Module Handbook
Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
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KIT DEPARTMENT OF MATHEMATICS
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Credits
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## Field of Study Structure

### Applied Mathematics

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1.4 Electrical Engineering / Information Technology

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Electrical Engineering / Information Technology (Election: between 15 and 24 credits)

Mandatory

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
## 1.5 Experimental Physics

### Credits
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### Experimental Physics (Election: between 15 and 24 credits)

| M-PHYS-106331 | Modern Experimental Physics I, Atoms, Nuclei and Molecules | 8 CR |
| M-PHYS-106332 | Modern Experimental Physics II, Structure of Matter | 8 CR |
| M-PHYS-102053 | Condensed Matter Theory I, Fundamentals and Advanced Topics | 12 CR |
| M-PHYS-102054 | Condensed Matter Theory I, Fundamentals | 8 CR |
| M-PHYS-102075 | Astroparticle Physics I | 8 CR |
| M-PHYS-102089 | Electronic Properties of Solids I, with Exercises | 10 CR |
| M-PHYS-102090 | Electronic Properties of Solids I, without Exercises | 8 CR |
| M-PHYS-102097 | Basics of Nanotechnology I | 4 CR |
| M-PHYS-102100 | Basics of Nanotechnology II | 4 CR |
| M-PHYS-102108 | Electronic Properties of Solids II, with Exercises | 8 CR |
| M-PHYS-102109 | Electronic Properties of Solids II, without Exercises | 4 CR |
| M-PHYS-102114 | Particle Physics I | 8 CR |
| M-PHYS-102175 | Introduction to Cosmology | 6 CR |
| M-PHYS-102277 | Theoretical Optics | 6 CR |
| M-PHYS-102295 | Theoretical Nanooptics | 6 CR |
| M-PHYS-102308 | Condensed Matter Theory II: Many-Body Theory, Fundamentals and Advanced Topics | 12 CR |
| M-PHYS-102313 | Condensed Matter Theory II: Many-Body Theory, Fundamentals | 8 CR |

## 1.6 Chemical and Process Engineering

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| M-CIWVT-103058 | Thermodynamics III | 6 CR |
| M-CIWVT-103059 | Statistical Thermodynamics | 6 CR |
| M-CIWVT-103063 | Thermodynamics of Interfaces | 4 CR |
| M-CIWVT-103065 | Biopharmaceutical Purification Processes | 6 CR |
| M-CIWVT-103066 | Process Modeling in Downstream Processing | 4 CR |
| M-CIWVT-103068 | Physical Foundations of Cryogenics | 6 CR |
| M-CIWVT-103069 | Combustion Technology | 6 CR |
| M-CIWVT-103072 | Computational Fluid Dynamics | 6 CR |
| M-CIWVT-103073 | Processing of Nanostructured Particles | 6 CR |
| M-CIWVT-103075 | High Temperature Process Engineering | 6 CR |

## 1.7 Wildcard Technical Field

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Computer Science (Election: at least 1 item as well as between 8 and 17 credits)
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## Field of Study Structure

### Mathematical Specialization

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#### Elective Field Mathematical Specialization (Election: at least 16 credits)

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## Additional Examinations (Election: at least 30 credits)

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<td>M-MATH-103700</td>
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<td>Numerical Linear Algebra for Scientific High Performance Computing</td>
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<td>Introduction to Kinetic Theory</td>
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<td>M-MATH-104261</td>
<td>Lie Groups and Lie Algebras</td>
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<td>M-MATH-104349</td>
<td>Bott Periodicity</td>
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<td>Dispersive Equations</td>
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<td>M-MATH-104435</td>
<td>Selected Topics in Harmonic Analysis</td>
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<td>Fourier Analysis and its Applications to PDEs</td>
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<td>Boundary Element Methods</td>
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<td>Splitting Methods for Evolution Equations</td>
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<td>Nonlinear Wave Equations</td>
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<td>M-MATH-105327</td>
<td>Numerical Simulation in Molecular Dynamics</td>
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<td>M-MATH-105650</td>
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<td>M-MATH-105837</td>
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<td>Selected Methods in Fluids and Kinetic Equations</td>
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<td>M-MATH-106695</td>
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<tr>
<td>M-MATH-106682</td>
<td>Numerical Methods for Oscillatory Differential Equations <strong>neu</strong></td>
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</table>
2 Modules

2.1 Module: Adaptive Finite Element Methods [M-MATH-102900]

Responsible: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

<table>
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Mandatory

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<td>Adaptive Finite Element Methods</td>
<td>6 CR</td>
<td>Dörfler</td>
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</table>

Competence Certificate
oral exam of ca. 25 minutes

Prerequisites
none

Competence Goal
Participants
• know the necessity for using adaptive methods
• are able to explain the basic methods, techniques and algorithms for the treatment of elliptic boundary value problems with adaptive finite element methods
• can describe different approaches for error estimation
• are able to solve simple boundary value problems numerically

Content
• Necessity of adaptive methods
• Residual error estimator
• Aspects of implementations
• Optimality of adaptive methods
• Functional error estimator
• hp-Finite Elements

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 h
• lectures, problem classes and examination
Self studies: 120 h
• follow-up and deepening of the course content
• work on problem sheets
• literature study and internet research on the course content
• preparation for the module examination

Recommendation
Basic knowledge in finite element methods, in programming and analysis of boundary value problems is strongly recommended. Knowledge in functional analysis is recommended.
2.2 Module: Advanced Inverse Problems: Nonlinearity and Banach Spaces [M-MATH-102955]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

<table>
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**Mandatory**
- T-MATH-105927 Advanced Inverse Problems: Nonlinearity and Banach Spaces
  - 5 CR
  - Rieder

**Competence Certificate**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Prerequisites**
none

**Competence Goal**
Graduates are familiar with regularization methods for nonlinear ill-posed problems in Hilbert and Banach spaces and can discuss the underlying analytical and numerical aspects. They are also able to explain the conceptual differences between regularization methods in Hilbert and Banach spaces.

**Content**
- Inexact Newton methods in Hilbert spaces,
- Approximate Inverse in Banach spaces
- Tikhonov regularization with convex penalty
- Kaczmarz-Newton methods in Banach spaces

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 150 hours

- Attendance: 60 hours
  - lectures, problem classes, and examination

- Self-studies: 90 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**
Inverse problems, Functional analysis
2.3 Module: Algebra [M-MATH-101315]

**Responsible:** PD Dr. Stefan Kühnlein  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Credits:** 8  
**Grading scale:** Grade to a tenth  
**Recurrence:** Each winter term  
**Duration:** 1 term  
**Level:** 4  
**Version:** 2

**Mandatory**

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<td>8 CR</td>
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</table>

**Competence Certificate**

Oral examination of ca. 30 minutes.

**Prerequisites**

None

**Competence Goal**

Students are able to

- understand essential concepts from Algebra,
- apply results from Galois theory to concrete situations,
- name basic results concerning discrete valuations and relate them to integral ring extensions.

They are prepared to write a thesis on a topic from algebra.

**Content**

- algebraic field extensions, Galois theory, roots of unit, applications of Galois theory  
- discrete valuations, discrete valuation rings  
- Tensor products of modules, integral ring extensions, normalization, noetherian rings, Hilbert's Basis Theorem

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 240 hours.

Attendance: 90 h

- lectures and tutorials including the examination

Self studies: 150 h

- follow-up and deepening of the course content  
- work on problem sheets  
- literature study and internet research on the course content  
- preparation for the module examination

**Recommendation**

Basic knowledge on groups and rings is beneficial.
Module: Algebraic Geometry [M-MATH-101724]

Responsible: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits: 8
Grading scale: Grade to a tenth
Recurrence: Irregular
Duration: 1 term
Level: 4
Version: 1

Mandatory

| T-MATH-103340 | Algebraic Geometry | 8 CR | Herrlich, Kühnlein |

Competence Certificate
The module will be completed by an oral exam of about 30 minutes.

Prerequisites
None

Competence Goal
Participants are able to

- name and discuss basic concepts concerning algebraic varieties
- apply algebraic tools, in particular those from the theory of polynomial rings, to geometric questions
- explain important results from classical algebraic geometry and their application in specific examples
- start to read recent research papers from algebraic geometry and write a thesis in this area.

Content

- Hilbert's Nullstellensatz
- affine and projective varieties
- morphisms and rational maps
- non-singular varieties
- algebraic curves
- Riemann-Roch-Theorem

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total work load:
Attendance: 90 minutes
- lectures, problem classes an examination
Self studies: 150 hours
- follow-up and deepening of the course contents
- work on problem sheets
- literature study and internet research relating to the course contents
- Preparation of the oral exam

Recommendation
The contents of basic courses on algebra and number theory, including basic commutative algebra, should be well-understood.
Module: Algebraic Number Theory [M-MATH-101725]

**Responsible:** PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Credits:** 8

**Grading scale:** Grade to a tenth

**Recurrence:** Irregular

**Duration:** 1 term

**Level:** 4

**Version:** 1

**Mandatory**

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<tr>
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<th>Course Title</th>
<th>CR</th>
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</thead>
</table>
| T-MATH-103346 | Algebraic Number Theory      | 8 CR | Herrlich, Kühnlein

**Competence Certificate**
oral examination of ca. 30 minutes

**Prerequisites**
none

**Competence Goal**
Students are able to

- understand basic structures and concepts from algebraic number theory,
- apply abstract concepts to concrete problems,
- read research papers and write a thesis in the field of algebraic number theory.

**Content**

- Algebraic number fields: rings of integers, Minkowski theory, class-groups and Dirichlet's unit theorem,
- Extensions of number fields: Ramified primes, Hilbert's ramification theory,
- Local fields: Ostrowski's theorem, valuation theory, Hensel's lemma, extensions of local fields,
- analytic methods: Dirichlet series, Dedekind's zeta function, L-series

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
Total workload: 240 hours

- Attendance: 90 h
  - lectures, problem classes and examination

- Self studies: 150 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination

**Recommendation**
The contents of the module "Algebra" are strongly recommended.
# 2.6 Module: Algebraic Topology [M-MATH-102948]

**Responsible:** Prof. Dr. Roman Sauer  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**

| T-MATH-105915 | Algebraic Topology | 8 CR | Krannich, Sauer |

**Prerequisites**  
none
2.7 Module: Algebraic Topology II [M-MATH-102953]

Responsible: Prof. Dr. Roman Sauer

Organisation: KIT Department of Mathematics

Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 8
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Level 4
Version 1

Mandatory

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Prerequisites
none
2.8 Module: Analytical and Numerical Homogenization [M-MATH-105636]

Responsible: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)
          Additional Examinations

Credits: 6  Grading scale: Grade to a tenth  Recurrence: Irregular  Duration: 1 term  Level: 4  Version: 1

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<td>Analytical and Numerical Homogenization</td>
<td>6 CR</td>
<td>Hochbruck, Maier</td>
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</table>

Prerequisites
none

Competence Goal
The topic of the lecture are numerical multiscale methods presented exemplarily for elliptic problems. Students know the basic analytical results for existence and uniqueness of the solution of multiscale problems and from homogenization theory. In addition, they know methods for the numerical approximation of multiscale and the homogenized solution. They are able to analyze the convergence of these methods and asses the pros and cons of the different approaches.

Content
- Analytical fundamentals (basic results from analysis for elliptic partial differential equations and from homogenization theory)
- Approximation of the homogenized solution (e.g. heterogeneous multiscale method)
- Approximation of the multiscale solution (e.g. local orthogonal decomposition)

Annotation
Upon request the lecture will be held in english.
### 2.9 Module: Applications of Topological Data Analysis [M-MATH-105651]

**Responsible:** Dr. Andreas Ott  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**

| T-MATH-111290 | Applications of Topological Data Analysis | 4 CR | Ott |

**Prerequisites**

None
2.10 Module: Aspects of Geometric Analysis [M-MATH-103251]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

**Mandatory**

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**Competence Certificate**
oral exam; duration: about 20 minutes

**Prerequisites**
none

**Competence Goal**
- The students have got to know topics of Geometric analysis.
- They are able to use and explain the techniques they have learned in the course.

**Content**
Classical or recent topics of Geometric analysis, for example

- Geometric evolution equations,
- Geometric variational problems,
- The theory of minimal surfaces,
- Regularity of geometric objects,
- The isoperimetric problem,
- Spectral theory on manifolds.

**Recommendation**
Elementare Geometrie, Klassische Methoden partieller Differentialgleichungen/Partial differential equations, Functional analysis
### 2.11 Module: Astroparticle Physics I [M-PHYS-102075]

**Responsible:** Prof. Dr. Guido Drexlin  
Prof. Dr. Kathrin Valerius

**Organisation:** KIT Department of Physics

**Part of:** Experimental Physics (Experimental Physics)

<table>
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**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Competence Goal**

Students will be introduced to the basic concepts of astroparticle physics. The lecture teaches both the theoretical concepts and the experimental methods of this new dynamic field of work at the interface of elementary particle physics, cosmology and astrophysics. Students will learn to understand the concepts through concrete case studies from current research and will be enabled to apply the learned methods independently.

**Methodological skills acquisition:**

- Understanding of the fundamentals of experimental astroparticle physics.
- Recognition of methodological cross-connections to elementary particle physics, astrophysics, and cosmology.
- Acquisition of the ability to present a current research topic independently as well as in a team setting
- Acquisition of the ability to implement the concepts and experimental methods in the master thesis

**Content**

The topics covered include a general introduction to the field with its fundamental issues, theoretical concepts and experimental methods. Corresponding to the very different energy scales (meV - 1020 eV) of astroparticle physics, the lecture is divided into a discussion of the processes in the thermal (low energies) and non-thermal (high energies) universe. A special focus of the lecture is a comprehensive presentation of modern experimental techniques, e.g. in the search for very rare processes. Based on this, in the second part of the lecture a comprehensive introduction to the "dark universe" and the search for dark matter is given.

The lecture is the basis of further lectures on this topic (Astroparticle Physics II).

**Workload**

240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours)

**Recommendation**

Basic knowledge from the lecture "Nuclei and Particles".

**Literature**

- Donald Perkins, Particle Astrophysics (Oxford University Press, 2. Auflage, 2009)
- Claus Grupen, Astroparticle Physics (Springer, 2005)
Module: Banach Algebras [M-MATH-102913]

Responsible: PD Dr. Gerd Herzog
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Mandatory
T-MATH-105886 Banach Algebras 3 CR Herzog

Competence Certificate
The module will be completed by an oral exam (about 20 min).

Prerequisites
none

Competence Goal
At the end of the course, students can

- name, discuss and apply basic statements of the theory of Banach algebras,
- use specific techniques from ideal theory, spectral theory and functional calculus in Banach algebras.

Content
1. Banach and operator algebras
2. Multiplicative linear functionals
3. Spectrum and resolvents
4. Commutative Banach algebras
5. Corona Theorem
6. Functional calculus in Banach algebras
7. B*-algebras
8. Ordered Banach algebras

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 90 hours
Attendance: 30 hours

- lectures, problem classes, and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
Knowledge of complex analysis (e.g. from Analysis 4) is recommended.
Module: Basics of Nanotechnology I [M-PHYS-102097]

Responsible: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: Experimental Physics (Experimental Physics)

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Mandatory

| T-PHYS-102529 | Basics of Nanotechnology I | 4 CR | Goll |

Competence Certificate

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Prerequisites

none

Competence Goal

Students deepen their knowledge in one area of nano-physics, master the relevant theoretical concepts and are familiar with basic techniques and measurement methods of nano-analytics and lithography.

Content

Introduction to central areas of nanotechnology;
Teaching of the conceptual, theoretical and, in particular, methodological fundamentals:

- Methods of imaging and characterization (nanoanalytics)
  Basic concepts of electron microscopy and associated analytical capabilities are covered in an introductory manner. Scanning probe techniques such as tunneling and force microscopy for the investigation and imaging of conductive and insulating sample surfaces, respectively, are discussed. Complementary spectroscopic capabilities of the scanning probe techniques will be explained.
- Methods of nanostructure fabrication (lithography and self-assembly)
  Along the individual process steps from coating and exposure to structure transfer by etching and vapor deposition, the methods used will be explained, their application limits discussed and current developments highlighted.

The lecture "Nanotechnology II" covers application areas and current research topics in the summer semester.

Workload

120 hours consisting of attendance time (30 hours), wrap-up of lecture incl. exam preparation. (90 hours)

Recommendation

Basic knowledge of solid state physics and quantum mechanics is expected.

Literature

For follow-up and consolidation of the lecture material, reference is made to various textbooks as well as original and review articles. A detailed list will be given in the lecture.
Module: Basics of Nanotechnology II [M-PHYS-102100]

**Responsible:** apl. Prof. Dr. Gernot Goll  
**Organisation:** KIT Department of Physics  
**Part of:** Experimental Physics (Experimental Physics)

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<td>T-PHYS-102531</td>
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**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Competence Goal**

The student deepens his knowledge in the field of nanophysics, masters the relevant theoretical concepts and is familiar with the basic application areas of nanophysics. The student is able to interpret current data and figures from the scientific literature and to present the current state of research as well as important "open questions".

**Content**

Introduction to central areas of nanotechnology  
Teaching of the conceptual, theoretical and especially methodological basics;  
Applications and current developments in the fields of nanoelectronics, nanooptics, nanomechanics, nanotribology, biological nanostructures, self-organized nanostructures, among others.  
In addition, the lecture "Fundamentals of Nanotechnology I" in the winter semester deals with methods of imaging, characterization and fabrication of nanostructures.

**Workload**

120 hours consisting of attendance time (30 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (90 hours)

**Recommendation**

Basic knowledge of solid state physics and quantum mechanics is expected.

**Literature**

For follow-up and consolidation of the lecture material, reference is made to various textbooks as well as original and review articles. A detailed list will be given in the lecture.
2.15 Module: Batteries and Fuel Cells [M-ETIT-100532]

**Responsible:** Prof. Dr.-Ing. Ulrike Krewer

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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**Prerequisites**

none
Module: Bayesian Inverse Problems with Connections to Machine Learning [M-MATH-106328]

**2.16 Module: Bayesian Inverse Problems with Connections to Machine Learning [M-MATH-106328]**

**Responsible:** TT-Prof. Dr. Sebastian Krumscheid  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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<td>Bayesian Inverse Problems with Connections to Machine Learning</td>
<td>4 CR</td>
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</table>

**Competence Certificate**  
oral exam of ca. 30 min

**Prerequisites**  
None

**Competence Goal**  
After completing the module's classes and the exam, students will be familiar with the theory of inverse problems. They will be able to apply the Bayesian framework to a given inverse problem and assess the well-posedness of the Bayesian posterior. In addition, students will be able to describe the basics of several solution methods for accessing the Bayesian posterior, including approximation and machine-learning techniques, and their limitations. Finally, they will be able to name and discuss essential theoretical concepts for Bayesian inversion in Banach spaces and describe the suitable sampling-based solution techniques. In particular, the course prepares students to write a thesis in the field of Uncertainty Quantification.

**Content**  
The course offers an introduction to the subject of statistical inversion, where, in its most basic form, the goal is to study how to estimate model parameters from data. We will introduce mathematical concepts and computational tools for systematically treating these inverse problems in a Bayesian framework, including an assessment of how uncertainties affect the solution. In the first part of the course, we will study the Bayesian framework for finite-dimensional inverse problems. While the first part will introduce some machine-learning ideas, the second part will address how machine learning is impacting, and has the potential to impact further on, the subject of inverse problems. In the final part of the course, we will generalize the Bayesian inverse problem theory to a Banach space setting and discuss sampling strategies for accessing the Bayesian posterior.

Topics covered include:

- Bayesian Inverse Problems and Well-Posedness  
- The Linear-Gaussian Setting  
- Optimization Perspective on Bayesian Inverse Problems  
- Gaussian Approximation  
- Markov Chain Monte Carlo  
- Blending Inverse Problems and Machine-Learning  
- Bayesian Inversion in Banach spaces

**Module grade calculation**  
The grade of the module is the grade of the oral exam.

**Workload**  
total workload: 120 hours

**Recommendation**  
The contents of the modules 'M-MATH-101321 - Introduction to Stochastics', 'M-MATH-103214 – Numerical Mathematics 1+2', and 'M-MATH-106053 — Stochastic Simulation' are recommended.
Module: Bifurcation Theory [M-MATH-103259]

**Responsible:** Dr. Rainer Mandel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Prerequisites**

None

**Annotation**

Course is held in English
M 2.18 Module: Biopharmaceutical Purification Processes [M-CIWVT-103065]

**Responsible:** Prof. Dr. Jürgen Hubbuch

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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**Mandatory**

| T-CIWVT-106029 | Biopharmaceutical Purification Processes | 6 CR | Hubbuch |

**Competence Certificate**
The examination is a written examination with a duration of 120 minutes (section 4 subsection 2 number 1 SPO). The grade of the written examination is the module grade.

**Prerequisites**
None

**Competence Goal**
Process development of biopharmaceutical processes

**Content**
Detailed discussion of biopharmaceutical purification processes

**Workload**
- Attendance time (Lecture): 60 h
- Homework: 90 h
- Exam Preparation: 30 h

**Learning type**
- 22705 - Biopharmazeutische Aufarbeitungsverfahren, 3V
- 22706 - Übung zu Biopharmazeutische Aufarbeitungsverfahren, 1Ü

**Literature**
Vorlesungsskript
2.19 Module: Bott Periodicity [M-MATH-104349]

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Grading scale:** Grade to a tenth

**Recurrence:** Irregular

**Duration:** 1 term

**Level:** 4

**Version:** 1

**Prerequisites**

None
Module: Boundary and Eigenvalue Problems [M-MATH-102871]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

**Credits**
8

**Grading scale**
Grade to a tenth

**Recurrence**
Each summer term

**Duration**
1 term

**Level**
4

**Version**
1

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<td>Each summer term</td>
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**Competence Certificate**
The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to

- assess the significance of boundary value and eigenvalue problems within mathematics and/or physics and illustrate them using examples,
- describe qualitative properties of solutions,
- prove the existence of solutions to boundary value problems using functional analysis methods,
- make statements about the existence of eigenvalues and eigenfunctions of elliptic differential operators and describe their properties.

**Content**

- Examples of boundary and eigenvalue problems
- Maximum principles for 2nd order equations
- Function spaces, e.g. Sobolev spaces
- Weak formulation of 2nd order linear elliptic equations
- Existence and regularity theory for elliptic equations
- Eigenvalue theory for weakly formulated elliptic eigenvalue problems

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 240 hours

- Attendance: 90 hours
  - lectures, problem classes, and examination

- Self-studies: 150 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination
### 2.21 Module: Boundary Element Methods [M-MATH-103540]

**Responsible:** PD Dr. Tilo Arens  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**  
| T-MATH-109851 | Boundary Element Methods | 8 CR | Arens |

**Competence Certificate**  
The examination is carried out by an oral examination (approx. 30 minutes).

**Prerequisites**  
None

**Competence Goal**  
Students are able to apply the analytic foundations of defining potentials and boundary operators, such as distributions, Sobolev spaces on boundaries of Lipschitz domains and trace operators to specific problems. They understand the definition of potentials, boundary operators and important mathematical statements about them. They are able to formulate boundary integral equations for concrete elliptic boundary value problems and to comprehend the proofs for their solvability.

Students are able to name and describe classes of boundary elements. They are familiar with the use of various boundary elements for numerically solving boundary integral equations by Galerkin methods. They can explain results on convergence of such methods. The students can describe techniques for improving practical handling of boundary element methods such as matrix compression schemes and preconditioning.

**Content**
- Sobolev spaces  
- function spaces on Lipschitz boundaries  
- boundary value problems for elliptic partial differential equations  
- potentials and boundary operators  
- boundary integral equations  
- boundary elements  
- Galerkin boundary element methods  
- preconditioning  
- matrix compression

**Module grade calculation**  
The module grade is the grade of the oral examination.

**Workload**  
Total workload: 240 hours  
Attendance: 90 h  
- lectures, problem classes and examination  
Self studies: 150 h  
- increased understanding of module content by wrapping up lectures at home  
- work on exercises  
- increased understanding of module content by self study of literature and internet research  
- preparing for the examination

**Recommendation**  
We recommend attendance of the module "Numerical Methods for Integral Equations".
### Module: Boundary value problems for nonlinear differential equations [M-MATH-102876]

**Responsible:** Prof. Dr. Wolfgang Reichel  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Analysis)  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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<td>Plum, Reichel</td>
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**Competence Certificate**

The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**

None

**Competence Goal**

Graduates will be able to

- assess the significance of non-linear boundary value problems in relation to their applications in the natural and engineering sciences and illustrate them using examples,
- describe qualitative properties of solutions,
- prove the existence of solutions using functional analytical methods,
- recognize and analyze non-linear phenomena (e.g. bifurcation, multiplicity of solutions) and illustrate them using prototypical examples.

**Content**

- Method of upper and lower solutions  
- Existence using fixed point methods  
- Qualitative properties  
- Variational methods and/or bifurcation theory

**Module grade calculation**

The module grade is the grade of the oral/written exam.

**Workload**

Total workload: 240 hours  
Attendance: 90 hours  
- lectures, problem classes, and examination  
Self-studies: 150 hours  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination

**Recommendation**

The contents of the courses 'Functional Analysis', 'Classical Methods for Partial Differential Equations' and 'Boundary and Eigenvalue Problems' are recommend.
2.23 Module: Brownian Motion [M-MATH-102904]

**Responsible:** Prof. Dr. Nicole Báuerle

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

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**Additional Examinations**

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<td>T-MATH-105868</td>
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**Competence Certificate**
The module will be completed by an oral exam (about 20 min).

**Prerequisites**
none

**Competence Goal**
At the end of the course, students
- can name, explain and justify properties of the Brownian motion,
- can use the Brownian motion to model stochastic phenomenon,
- can use specific probabilistic techniques,
- are able to work in a self-organized and reflective manner.

**Content**
- Existence and construction of Brownian motion,
- path properties of Brownian motion,
- strong Markov property of Brownian motion with applications,
- Skorokhod representation theorems with Brownian motion.

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 120 hours
Attendence: 45 hours
- lectures, problem classes, and examination
Self-studies: 72 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**
The course 'Probability Theory' is strongly recommended.
### 2.24 Module: Classical Methods for Partial Differential Equations [M-MATH-102870]

| Responsible: | Prof. Dr. Michael Plum |
| Organisation: | KIT Department of Mathematics |
| Part of: | Applied Mathematics (Analysis)  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
Additional Examinations |

| Credits | 8 |
| Grading scale | Grade to a tenth |
| Recurrence | Each winter term |
| Duration | 1 term |
| Level | 4 |
| Version | 1 |

| Mandatory |
| T-MATH-105832 | Classical Methods for Partial Differential Equations | 8 CR Frey, Hundertmark, Lamm, Plum, Reichel, Schnaubelt |
## 2.25 Module: Cognitive Systems [M-INFO-100819]

**Responsible:** Prof. Dr. Gerhard Neumann  
Prof. Dr. Alexander Waibel  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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### Mandatory

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<thead>
<tr>
<th>T-INFO-101356</th>
<th>Cognitive Systems</th>
<th>6 CR</th>
<th>Neumann, Waibel</th>
</tr>
</thead>
</table>
**2.26 Module: Combinatorics [M-MATH-102950]**

**Responsible:** Prof. Dr. Maria Aksenovich  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
Additional Examinations

<table>
<thead>
<tr>
<th>Credits</th>
<th>Grading scale</th>
<th>Recurrence</th>
<th>Duration</th>
<th>Language</th>
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<td>8</td>
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</table>

**Mandatory**

| T-MATH-105916 | Combinatorics | 8 CR | Aksenovich |

**Competence Certificate**

The final grade is given based on the written final exam (2h).

By successfully working on the problem sets, a bonus can be obtained. To obtain the bonus, one has to achieve 50% of the points on the solutions of the exercise sheets 1-6 and also of the exercise sheets 7-12. If the grade in the final written exam is between 4,0 and 1,3, then the bonus improves the grade by one step (0,3 or 0,4).

**Prerequisites**

none

**Competence Goal**

The students understand, describe, and use fundamental notions and techniques in combinatorics. They can analyze, structure, and formally describe typical combinatorial questions. The students can use the results and methods such as inclusion-exclusion, generating functions, Young tableaux, as well as the developed proof ideas, in solving combinatorial problems. In particular, they can analyze the existence and the number of ordered and unordered arrangements of a given size. The students understand and critically use the combinatorial methods. Moreover, the students can communicate using English technical terminology.

**Content**

The course is an introduction into combinatorics. Starting with counting problems and bijections, classical methods such as inclusion-exclusion principle and generating functions are discussed. Further topics include Catalan families, permutations, Young tableaux, partial orders, and combinatorial designs.

**Module grade calculation**

The grade of the module ist the grade of the written exam.

**Annotation**

- Regular cycle: every 2nd year, summer semester
- Course is held in English

**Workload**

Total workload: 240 hours  
Attendance time: 90 hours

- Course including module examination during the course of study

Self-study: 150 hours

- Deepening the study content by working on the lecture content at home
- Completion of exercises
- In-depth study of the course content using suitable literature and internet research
- Preparation for the module examination during the course of study

**Recommendation**

Knowledge of the modules Linear Algebra 1 and 2 and Analysis 1 and 2 is recommended.
Module: Combustion Technology [M-CIWVT-103069]

Responsible: Prof. Dr.-Ing. Dimosthenis Trimis
Organisation: KIT Department of Chemical and Process Engineering
Part of: Chemical and Process Engineering (Chemical and Process Engineering)

<table>
<thead>
<tr>
<th>Credits</th>
<th>Grading scale</th>
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Mandatory

| T-CIWVT-106104 | Combustion Technology | 6 CR | Trimis |

Competence Certificate
Learning Control is an oral examination with a duration of about 20 minutes (section 4 subsection 2 SPO). Grade of the module is the grade of the oral examination.

Prerequisites
None

Competence Goal
- The students are able to describe and explain the characteristics of the different flame types.
- The students can quantitatively estimate/calculate major combustion characteristics like flame temperature and flame velocity. They further understand the physicochemical mechanisms affecting flammability limits and quenching distances.
- The students understand and can assess the influence/interaction of turbulence, heat and mass transfer to reacting flows.
- The students understand the flame structure and the hierarchical structure of reaction kinetic mechanisms.
- The students understand and can assess the influence of interaction between different time scales of chemical kinetics and fluid flow in reacting flows.
- The students are able to assess and evaluate burner operability with regard to the application.

Content
- Introduction and significance of combustion technology
- Thermodynamics of combustion: Mass and energy/enthalpy balances
- Equilibrium composition
- Flame temperature
- Reaction mechanisms in combustion processes
- Laminar flame velocity and thermal flame theory
- Kinetics related combustion characteristics and experimental characterization: laminar flame velocity, flammability limits, ignition temperature, ignition energy, ignition delay time, quenching distance, flash point, octane and cetane number
- Turbulent flame propagation
- Industrial burner types

Workload
- Lectures and Exercises: 45 h
- Homework: 25 h
- Exam Preparation: 110 h

Literature
2.28 Module: Comparison Geometry [M-MATH-102940]

**Responsible:** Prof. Dr. Wilderich Tuschmann

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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<td>Comparison Geometry</td>
<td>5 CR</td>
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**Prerequisites**

none
2.29 Module: Complex Analysis [M-MATH-102878]

**Responsible:** PD Dr. Gerd Herzog

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

**Credits**
- 8

**Grading scale**
- Grade to a tenth

**Recurrence**
- Irregular

**Duration**
- 1 term

**Level**
- 4

**Version**
- 1

**Mandatory**

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</table>

**Competence Certificate**
The module will be completed by an oral exam (about 30 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students can

- explain the basic concepts and results of the theory of infinite products and apply them in examples within the framework of Weierstrass's theorems
- reproduce the Mittag-Leffler theorem and derive conclusions from it
- explain Riemann's mapping theorem and are able to describe what Montel's theorem is and how this theorem is included in the proof of Riemann's theorem
- name the most important properties of class S of simple functions and formulate the (proven) Bieberbach conjecture
- explain the basic concepts of the theory of harmonic functions and apply them in examples
- explain the Schwarz reflection principle.
- describe properties of regular and singular points in power series and discuss them with examples.

**Content**

- infinite products
- Mittag-Leffler's theorem
- Montel's theorem
- Riemann's mapping theorem
- conformal mappings
- univalent (schlicht) functions
- automorphisms of some domains
- harmonic functions
- Schwarz reflection principle
- regular and singular points of power series

**Module grade calculation**
The module grade is the grade of the oral exam.
Workload
Total workload: 240 hours
Attendance: 90 hours
  • lectures, problem classes, and examination
Self-studies: 150 hours
  • follow-up and deepening of the course content,
  • work on problem sheets,
  • literature study and internet research relating to the course content,
  • preparation for the module examination

Recommendation
Basics of complex analysis, for example from the “Analysis 4” module, are recommended.
2.30 Module: Compressive Sensing [M-MATH-102935]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

**Credits** | **Grading scale** | **Recurrence** | **Duration** | **Level** | **Version**
--- | --- | --- | --- | --- | ---
5 | Grade to a tenth | Irregular | 1 term | 4 | 1

| Mandatory |
|---|---|---|
| T-MATH-105894 | Compressive Sensing | 5 CR | Rieder |

**Competence Certificate**
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

**Competence Goal**
Graduates can explain the ideas of compressive sensing and can name areas of application. They can apply and compare the basic algorithms and analyze their convergence behavior.

**Content**
- What is compressive sensing and where is it used?
- Sparse solutions of underdetermined linear systems of equations
- Basic algorithms
- Restricted isometry property
- Sparse solutions of underdetermined linear systems of equations with random matrices

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 150 hours
- **Attendance:** 60 hours
  - lectures, problem classes, and examination
- **Self-studies:** 90 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**
The course "Introduction to stochastics" is recommended.
# 2.31 Module: Computational Fluid Dynamics [M-CIWVT-103072]

**Responsible:** Prof. Dr.-Ing. Hermann Nirschl  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

<table>
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<th>Language</th>
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<td>CR Nirschl</td>
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</table>

**Competence Certificate**  
Learning control is a written examination lasting 90 minutes

**Prerequisites**  
None

**Competence Goal**  
Learning the fundamentals of CFD for the calculation of flow problems.

**Content**  
Navier-Stokes equations, numerical schemes, turbulence, multiphase flows.

**Module grade calculation**  
The module grade is the grade of the written examination.

**Workload**

- Attendance time (Lecture): 64 h  
- Homework: 56 h  
- Exam Preparation: 601 h

**Literature**

- Nirschl: Skript zur Vorlesung CFD  
- Ferziger, Peric: Numerische Strömungsmechanik  
- Oertel, Laurien: Numerische Strömungsmechanik
Module: Computational Fluid Dynamics and Simulation Lab [M-MATH-106634]

### Responsible:
PD Dr. Gudrun Thäter

### Organisation:
KIT Department of Mathematics

### Part of:
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

### Credits
4

### Grading scale
Grade to a tenth

### Recurrence
Each summer term

### Duration
1 term

### Language
German/English

### Level
4

### Version
2

### Mandatory
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</table>

### Competence Certificate
For their final project, students prepare a written report, usually 10-15 pages long, which is graded.

### Prerequisites
none

### Competence Goal
Students are able to jointly model problems beyond their own discipline and simulate them on high-performance computers. They have acquired a critical distance to results and their presentation. They can defend the results of projects in disputes. They have understood the importance of stability, convergence and parallelism of numerical methods from their own experience and are able to evaluate errors in modeling, approximation, computing and presentation.

### Content
**Lecture part:** Introduction to modeling and simulations, introduction to associated numerical methods, introduction to associated software and high-performance computer hardware

**Own group work:** Working on 1-2 projects in which modelling, discretization, simulation and evaluation (e.g. visualization) are carried out for specific topics from the catalog. The catalog includes e.g: Diffusion processes, turbulent flows, multiphase flows, reactive flows, particle dynamics, optimal control and optimization under constraints, stabilization methods for advection-dominated transport problems.

### Module grade calculation
The module grade is the grade of the final project.

### Workload
Total workload: 120 hours
Attendence: 60 hours
- lectures and examination

Self-studies: 60 hours
- follow-up and deepening of the course content,
- work on projects and report,
- literature study and internet research relating to the course content

### Recommendation
Basic knowledge of the analysis of boundary value problems and of numerical methods for differential equations is recommended. Knowledge of a programming language is strongly recommended.
2.33 Module: Computer Architecture [M-INFO-100818]

**Responsible:** Prof. Dr. Wolfgang Karl

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

<table>
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<th>Credits</th>
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</table>

**Mandatory**

| T-INFO-101355 | Computer Architecture | 6 CR | Karl |

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
### Module: Computer Graphics [M-INFO-100856]

**Responsible:** Prof. Dr.-Ing. Carsten Dachsbacher  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

<table>
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<th>Credits</th>
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<td>T-INFO-104313</td>
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2.35 Module: Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems [M-MATH-102883]

**Responsible:** Prof. Dr. Michael Plum

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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Mandatory

| T-MATH-105854 | Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems | 8 CR | Plum |
2 MODULES

Module: Condensed Matter Theory I, Fundamentals [M-PHYS-102054]

M

2.36 Module: Condensed Matter Theory I, Fundamentals [M-PHYS-102054]

Responsible: Prof. Dr. Markus Garst
Prof. Dr. Alexander Mirlin
Prof. Dr. Alexander Shnirman

Organisation: KIT Department of Physics

Part of: Experimental Physics (Experimental Physics)

Credits 8
Grading scale Grade to a tenth
Recurrence Each winter term
Duration 1 term
Language English
Level 4
Version 1

Mandatory

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<tr>
<td>T-PHYS-102559</td>
<td>Condensed Matter Theory I, Fundamentals</td>
<td>8 CR</td>
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</table>

Garst, Mirlin, Shnirman

Competence Certificate

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Exercises are offered to complement the lecture. Prerequisite for the participation in the oral module final examination is the passing of the course work in the exercises. The course work takes place in the form of exercises. To pass, 50% of the exercises must be passed.

Prerequisites

none

Modeled Conditions

The following conditions have to be fulfilled:

1. The module M-PHYS-102053 - Condensed Matter Theory I, Fundamentals and Advanced Topics must not have been started.

Competence Goal

Gaining understanding of phenomena and concepts in condensed matter theory, mastering basic theoretical tools for their description, and acquiring the ability to analyze and solve theoretically a limited class of problems in the field of condensed matter physics.

Content

Lectures and exercises convey and deepen the basic concepts of condensed matter theory, particular attention is paid to crystalline solids. The main subjects of the lecture are:

- Crystal lattices, electrons in periodic potentials, dynamics of Bloch electrons;
- Electronic transport properties of solids, Boltzmann equation;
- Solids in an external magnetic field: Pauli paramagnetism, Landau diamagnetism, de Haas-van Alphen effect;
- Electron-electron interaction, Stoner theory of ferromagnetism;
- Landau theory of Fermi liquids; Phonons and electron-phonon interaction

Workload

240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (180 hours).

Recommendation

Basic knowledge of solid state physics, quantum mechanics, statistical physics and thermodynamics is required.

Literature

- C. Kittel, Quantum Theory of Solids.
- A. A. Abrikosov, Fundamentals of the Theory of Metals
Module: Condensed Matter Theory I, Fundamentals and Advanced Topics [M-PHYS-102053]

Responsible: Prof. Dr. Markus Garst  
Prof. Dr. Alexander Mirlin  
Prof. Dr. Alexander Shnirman

Organisation: KIT Department of Physics  
Part of: Experimental Physics (Experimental Physics)

Credits: 12  
Grading scale: Grade to a tenth  
Recurrence: Each winter term  
Duration: 1 term  
Language: English  
Level: 4  
Version: 1

Mandatory

| T-PHYS-102558 | Condensed Matter Theory I, Fundamentals and Advanced Topics | 12 CR | Garst, Mirlin, Shnirman |

Competence Certificate
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Exercises are offered to complement the lecture. Prerequisite for the participation in the oral module final examination is the passing of the course work in the exercises. The course work takes place in the form of exercises. To pass, 50% of the exercises must be passed.

Prerequisites
none

Modeled Conditions
The following conditions have to be fulfilled:

1. The module M-PHYS-102054 - Condensed Matter Theory I, Fundamentals must not have been started.

Competence Goal
Gaining understanding of phenomena and concepts in condensed matter theory, mastering basic theoretical tools for their description, and acquiring the ability to analyze and solve theoretically a broader class of problems in the field of condensed matter physics.

Content
Lectures and exercises convey and deepen the basic concepts of condensed matter theory, particular attention is paid to crystalline solids. The main subjects of the lecture are:

- Crystal lattices, electrons in periodic potentials, dynamics of Bloch electrons;
- Electronic transport properties of solids, Boltzmann equation;
- Solids in the external magnetic field: Pauli paramagnetism, Landau diamagnetism, de Haas-van Alphen effect;
- Electron-electron interaction, Stoner theory of ferromagnetism;
- Landau theory of Fermi liquids; Phonons and electron-phonon interaction;
- Superconductivity: BCS theory, electrodynamics of superconductors, Ginzburg-Landau theory.

Workload
360 hours consisting of attendance time (90 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (270 hours)

Recommendation
Basic knowledge of solid state physics, quantum mechanics, statistical physics and thermodynamics is required.

Literature
- C. Kittel, Quantum Theory of Solids.
- A. A. Abrikosov, Fundamentals of the Theory of Metals
2.38 Module: Condensed Matter Theory II: Many-Body Theory, Fundamentals [M-PHYS-102313]

**Responsible:**
Prof. Dr. Markus Garst  
PD Dr. Igor Gornyi  
Prof. Dr. Alexander Mirlin  
PD Dr. Boris Narozhnyy  
Prof. Dr. Jörg Schmalian

**Organisation:**
KIT Department of Physics  
Part of: Experimental Physics (Experimental Physics)

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<td>8</td>
<td>CR</td>
<td>Garst, Gornyi, Mirlin, Narozhnyy, Schmalian</td>
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</table>

**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Exercises are offered to complement the lecture. Prerequisite for the participation in the oral module final examination is the passing of the course work in the exercises. The course work takes place in the form of exercises. To pass, 50% of the exercises must be passed.

**Prerequisites**

none

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-PHYS-102308 - Condensed Matter Theory II: Many-Body Theory, Fundamentals and Advanced Topics must not have been started.

**Competence Goal**

Mastering advanced field-theoretical approaches of condensed matter physics. Acquiring an ability to apply these methods for the solution of a limited class of advanced problems in the field of condensed matter physics.

**Content**

Estimated structure of the lecture:

1. Green's functions for non-interacting particles
2. Many-body Green's functions
3. Feynman diagrams (interacting fermions, Fermi fluids, collective excitations)
4. Green's functions and diagrammatic technique at finite temperatures (Matsubara diagrammatic technique)
5. Functional formulation of many-body theory
6. Superconducting systems
7. Non-equilibrium systems and Keldysh technique
8. Many-body systems in one dimension

**Workload**

240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and working on the exercises (180 hours).

**Recommendation**

In general this lecture should be attended after Theory of Condensed Matter I.
Literature

- A.A. Abrikosov, L.P. Gorkov, I.E. Dzyaloshinskii, Methods of QFT in statistical physics
- L.D. Landau, E.M. Lifschitz, Statistische Physik, Teil II (Lehrbuch der theoretischen Physik, Bd IX)
- G.D. Mahan, Many-particle physics
- A.L. Fetter, J.D. Vulecka, Quantum theory of many-particle systems.
- J.W. Negele, H. Orland, Quantum many-particle systems.
- J.R. Schrieffer, Theory of superconductivity.
- A. Altland, B. Simons, Condensed matter field theory.
- T. Giamarchi, Quantum physics in one dimension.
- A. Kamenev, Field theory of non-equilibrium systems.
Module: Condensed Matter Theory II: Many-Body Theory, Fundamentals and Advanced Topics [M-PHYS-102308]

**Responsible:**
- Prof. Dr. Markus Garst
- PD Dr. Igor Gornyi
- Prof. Dr. Alexander Mirlin
- PD Dr. Boris Narozhnyy
- Prof. Dr. Jörg Schmalian

**Organisation:**
- KIT Department of Physics
- Part of: Experimental Physics (Experimental Physics)

**Credits**
12

**Grading scale**
Grade to a tenth

**Recurrence**
Each summer term

**Duration**
1 term

**Language**
English

**Level**
4

**Version**
1

**Mandatory**

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<tr>
<td>T-PHYS-102560</td>
<td>Condensed Matter Theory II: Many-Body Systems, Fundamentals and Advanced Topics</td>
<td>12 CR</td>
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</table>

**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Exercises are offered to complement the lecture. Prerequisite for the participation in the oral module final examination is the passing of the course work in the exercises. The course work takes place in the form of exercises. To pass, 50% of the exercises must be passed.

**Prerequisites**
none

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-PHYS-102313 - Condensed Matter Theory II: Many-Body Theory, Fundamentals must not have been started.

**Competence Goal**

Mastering advanced field-theoretical approaches of condensed matter physics. Acquiring an ability to apply these methods for the solution of a broader class of advanced problems in the field of condensed matter physics.

**Content**

Estimated structure of the lecture:

1. Green's functions for non-interacting particles
2. Many-body Green's functions
3. Feynman diagrams (interacting fermions, Fermi fluids, collective excitations)
4. Green's functions and diagrammatic technique at finite temperatures (Matsubara diagrammatic technique)
5. Functional formulation of many-body theory
6. Superconducting systems
7. Non-equilibrium systems and Keldysh technique
8. Many-body systems in one dimension
9. Kondo effect
10. Strongly correlated electrons: Hubbard model and Mott metal-insulator transition
11. Introduction to mesoscopic physics

**Workload**

360 hours consisting of attendance time (90 hours), follow-up of the lecture incl. exam preparation and working on the exercises (270 hours)

**Recommendation**

In general this lecture should be attended after Theory of Condensed Matter I.
Literature

- A.A. Abrikosov, L.P. Gorkov, I.E. Dzyaloshinskii, Methods of QFT in statistical physics
- L.D. Landau, E.M. Lifschitz, Statistische Physik, Teil II (Lehrbuch der theoretischen Physik, Bd IX)
- G.D. Mahan, Many-particle physics
- A.L. Fetter, J.D. Valecka, Quantum theory of many-particle systems.
- J.W. Negele, H. Orland, Quantum many-particle systems.
- J.R. Schrieffer, Theory of superconductivity.
- A. Altland, B. Simons, Condensed matter field theory.
- T. Giamarchi, Quantum physics in one dimension.
- A. Kamenev, Field theory of non-equilibrium systems.
Module: Continuous Time Finance [M-MATH-102860]

Responsible: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 8
Grading scale Grade to a tenth
Recurrence Each summer term
Duration 1 term
Level 4
Version 1

Mandatory

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<td>T-MATH-105930</td>
<td>Continuous Time Finance</td>
<td>8</td>
<td>Grade to a tenth</td>
<td>Each summer term</td>
<td>1 term</td>
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</table>

Bäuerle, Fasen-Hartmann, Trabs

Competence Certificate
oral examination of ca. 30 min.

Prerequisites
The module cannot be completed together with "Stochastic Calculus and Finance [T-WIWI-103129]".

Competence Goal
Students are able to

- understand, describe and use fundamental notions and techniques of modern continuous time finance,
- use specific probabilistic techniques,
- analyze mathematically economical questions in option pricing and optimization

Content

- Stochastic processes and filtrations
  - Martingales in continuous time
  - Stopping times
  - Quadratic variation
- Stochastic Ito-Integral w.r.t. continuous semimartingales
- Ito-calculus
  - Ito-Doebelin formula
  - Stochastic exponentials
  - Girsanov theorem
  - Martingale representation
- Black-Scholes financial market
  - Arbitrage and equivalent martingale measures
  - Options and no-arbitrage prices
  - market completeness
- Portfolio optimization
- Bonds, forwards and interest rate models

Module grade calculation
The grade of the module is the grade of the oral exam.
Workload
Total workload: 240 hours
Attendance: 90 h
  • lectures, problem classes and examination
Self studies: 150 h
  • follow-up and deepening of the course content,
  • work on problem sheets
  • literature study and internet research on the course content,
  • preparation for the module examination

Recommendation
The content of the module „Probability theory“ is strongly recommended. The module „Discrete time finance“ is recommended.
Module: Control Theory [M-MATH-102941]

**Responsible:** Prof. Dr. Roland Schnaubelt  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

**Mandatory**

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**T-MATH-105909 Control Theory**  
6 CR  
Schnaubelt

**Competence Certificate**  
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**  
none

**Competence Goal**  
Students can explain the central concepts of the treatment of controlled linear ordinary differential equations (controllability, observability, stabilizability and discoverability) and the associated characterizations and apply them in examples. They are able to describe the basic features of the theory of transfer functions and realization theory. They can discuss the solution of the quadratic optimal control problem and apply it to feedback synthesis. They can describe the basic concepts of control theory including the associated criteria also for non-linear systems and apply them to examples.

**Content**

- controllability and observability of systems of linear ordinary differential equations  
- stabilizability and detectability  
- transfer functions  
- realization theory,  
- quadratic optimal control, feedback synthesis  
- nonlinear control theory: basic concepts, criteria via linearization, Lie brackets and Lyapunov functions

**Module grade calculation**  
The grade of the module is the grade of the oral exam.

**Workload**  
Total workload: 180 hours  
Attendance: 60 h  
- lectures, problem classes and examination  
Self studies: 120 h  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research on the course content,  
- preparation for the module examination

**Recommendation**  
The contents of the modules Analysis 1-2 und Lineare Algebra 1-2 are strongly recommended. Further knowledge of ordinary differential equations (as in Analysis 4) is useful.

**Literature**  
2.42 Module: Convex Geometry [M-MATH-102864]

Responsible: Prof. Dr. Daniel Hug
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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<th>Credits</th>
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Mandatory
T-MATH-105831 Convex Geometry 8 CR Hug

Competence Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None

Competence Goal
The students

- know fundamental combinatorial, geometric and analytic properties of convex sets and convex functions and apply these to related problems,
- are familiar with fundamental geometric and analytic inequalities for functionals of convex sets and their applications to geometric extremal problems and can present central ideas and techniques of proofs,
- know selected integral formulas for convex sets and the required results on invariant measures.
- know how to work self-organized and self-reflexive.

Content

1. Convex Sets
   1.1. Combinatorial Properties
   1.2. Support and Separation Properties
   1.3. Extremal Representations
2. Convex Functions
   2.1. Basic Properties
   2.2. Regularity
   2.3. Support Function
3. Brunn-Minkowski Theory
   3.1. Hausdorff Metric
   3.2. Volume and Surface Area
   3.3. Mixed Volumes
   3.4. Geometric Inequalities
   3.5. Surface Area Measures
   3.6. Projection Functions
4. Integralgeometric Formulas
   4.1. Invariant Measures
   4.2. Projection and Section Formula
   4.3 Kinematic Formula

Module grade calculation
The module grade is the grade of the oral exam.
**Workload**
Total workload: 240 hours

**Attendance:** 90 hours
- lectures, problem classes, and examination

**Self-studies:** 150 hours
- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research related to the course content
- preparation for the module exam.

**Literature**
# 2.43 Module: Curves on Surfaces [M-MATH-106632]

**Responsible:** Dr. Elia Fioravanti  
**Organisation:** KIT Department of Mathematics  
**Part of:** Mathematical Specialization (Elective Field Mathematical Specialization)  

<table>
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<th>Credits</th>
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<td>T-MATH-113364</td>
<td>Curves on Surfaces</td>
<td>3 CR</td>
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</table>

**Competence Certificate**  
The module will be completed by an oral exam (of ca. 20 - 30 min).

**Prerequisites**  
None

**Competence Goal**  
At the end of the course, students

- have a deeper understanding of the topology and geometry of surfaces, as well as of the structure of their homeomorphisms;
- are able to work independently and critically;
- are prepared to read recent research articles and work on a thesis on mapping class groups and related topics.

**Content**  
- curves on surfaces up to homotopy and isotopy,
- mapping class groups of surfaces,
- Nielsen-Thurston classification of homeomorphisms of surfaces,
- Teichmüller space.

**Module grade calculation**  
The module grade is the grade of the oral exam.

**Workload**  
Total workload: 90 hours  
Attendance: 30 hours

- lectures and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**  
The contents of the courses 'Introduction into Geometry and Topology' and 'Elementary Geometry' are recommended. The courses 'Hyperbolic Geometry' and 'Algebraic Topology' can facilitate a deeper understanding of the course contents.
# Module: Deep Learning and Neural Networks [M-INFO-104460]

**Responsible:** Prof. Dr. Jan Niehues  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

<table>
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<th>Credits</th>
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<td>Deep Learning and Neural Networks</td>
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## 2.45 Module: Differential Geometry [M-MATH-101317]

### Responsible
Prof. Dr. Wilderich Tuschmann

### Organisation
KIT Department of Mathematics

### Part of
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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### Mandatory

| T-MATH-102275 | Differential Geometry | 8 CR | Tuschmann |

### Prerequisites
None
2.46 Module: Discrete Dynamical Systems [M-MATH-105432]

**Responsible:** PD Dr. Gerd Herzog  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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### Mandatory

| T-MATH-110952 | Discrete Dynamical Systems | 3 CR | Herzog |

### Competence Certificate
The module will be completed by an oral exam (about 20 min).

### Prerequisites
None

### Competence Goal
At the end of the course, students can

- name, discuss and apply fundamental statements of the theory of discrete dynamic systems,  
- explain the meaning of dynamic systems using examples,  
- describe and use specific techniques of topological dynamics.

### Content

1. Discrete dynamical systems  
2. Chaotic dynamical systems  
3. Non-expansive mappings  
4. The Fürstenberg-Weiss theorem  
5. Cellular automata  
6. (Weakly) mixing dynamical systems  
7. Dynamics of linear operators

### Module grade calculation
The module grade is the grade of the oral exam.

### Workload
Total workload: 90 hours  
Attendance: 30 hours

- lectures, problem classes, and examination  
Self-studies: 60 hours

- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination

### Recommendation
Basics of complex analysis (e.g. from Analysis 4) and functional analysis are recommended.
Module: Discrete Time Finance [M-MATH-102919]

Responsible: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

Credits 8
Grading scale Grade to a tenth
Recurrence Each winter term
Duration 1 term
Level 4
Version 1

Mandatory

T-MATH-105839 Discrete Time Finance 8 CR Bäuerle, Fasen-Hartmann, Trabs

Competence Certificate
Written exam of 2h.

Prerequisites
none

Competence Goal
Students are able to

- understand, describe and use fundamental notions and techniques of modern discrete time finance,
- use specific probabilistic techniques,
- analyze mathematically economical questions in discrete option pricing and optimization,
- work self-organized and in a reflective manner.

Content

- Finite financial markets
- The Cox-Ross-Rubinstein-model
- Limit to Black-Scholes
- Characterizing no-arbitrage
- Characterizing completeness
- Incomplete markets
- American options
- Exotic options
- Portfolio optimization
- Preferences and stochastic dominance
- Mean-Variance portfolios
- Risk measures

Module grade calculation
The grade of the module is the grade of the written exam.

Workload
Total workload: 240 hours

Attendance: 90 h

- lectures and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The content of the module „Probability theory“ is strongly recommended.
2.48 Module: Dispersive Equations [M-MATH-104425]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

**Credits** 6

**Grading scale** Grade to a tenth

**Recurrence** Irregular

**Duration** 1 term

**Level** 4

**Version** 1

**Mandatory**

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<td>6 CR</td>
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</table>

**Competence Certificate**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
Graduates will be able to
- recognize the essential properties of dispersive partial differential equations and explain them using examples.
- name the particular difficulties of dispersive equations.
- use techniques to describe the short- and long-term behavior of solutions using the nonlinear Schrödinger equation as an example.
- analyze the stability of solitary waves.
- understand the concept of conservation variables and explain them for specific examples.

**Content**
- Strichartz estimates, Sobolev embeddings and conservation laws
- Well-posedness results
- Long-term behavior of solutions (virial and Morawetz identities)
- Orbital stability of solitary waves (variational description and concentration compactness)
- Energy conservation (invariant transmission coefficients)

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 180 hours

Attendance: 60 hours
- lectures, problem classes, and examination

Self-studies: 120 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**
The contents of the course 'Functional Analysis' are recommended.
2.49 Module: Dynamical Systems [M-MATH-103080]

**Responsible:** Prof. Dr. Wolfgang Reichel  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
Applied Mathematics (Analysis)  
Mathematical Specialization (Elective Field Mathematical Specialization)

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<td>Dynamical Systems</td>
<td>8</td>
<td>Reichel</td>
</tr>
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</table>

**Competence Certificate**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Graduates will be able to

- explain the significance of dynamical systems using examples,
- relate the concepts of a discrete-time and continuous-time dynamical system to each other,
- describe important methods for analyzing dynamical systems and use them to analyze the asymptotic behavior of solutions near equilibria for different dynamical systems,
- describe the behavior of invariant sets under discretization.

**Content**
- Examples of finite- and infinite-dimensional dynamical systems
- Fixed points, periodic orbits, limit sets
- Invariant sets
- Attractors
- Upper and lower continuity of attractors
- Stable and unstable manifolds
- Center manifolds

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 240 hours
Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**
The module 'Functional Analysis' is recommended.
Module: Electromagnetics and Numerical Calculation of Fields [M-ETIT-100386]

Responsible: Prof. Dr.-Ing. Thomas Zwick
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

Credits 4
Grading scale Grade to a tenth
Recurrence Each winter term
Duration 1 term
Language English
Level 4
Version 2

Mandatory
T-ETIT-100640 Electromagnetics and Numerical Calculation of Fields 4 CR Zwick

Competence Certificate
Success control is carried out in the form of a written test of 120 minutes.

Prerequisites
none

Competence Goal
Students with very different background in electromagnetic field theory will be brought to a high level of comprehension. They will understand the concept of electric & magnetic fields and of electric potential & vector potential and they will be able to solve simple problems of electric & magnetic fields using mathematics. They will understand the equations and solutions of wave creation and wave propagation. Finally the student will have learnt the basics of numerical field calculation and be able to use software packages of numerical field calculation in a comprehensive and critical way.

The student will

- be able to deal with all quantities of electromagnetic field theory (E, D, B, H, J, M, P, ...), in particular: how to calculate and how to measure them,
- derive various equations from the Maxwell equations to solve simple field problems (electrostatics, magnetostatics, steady currents, electromagnetics),
- be able to deal with the concept of field energy density and solve practical problems using it (coefficients of capacitance and coefficients of inductance),
- be able to derive and use the wave equation, in particular: to solve problems how to create a wave and calculate solutions of wave propagation through various media,
- be able to outline the concepts, the main application areas and the limitations of methods of numerical field calculation (FDM, FDTD, FIM, FEM, BEM, MoM, TLM)
- be able to use one exemplary software package of numerical field calculation and solve simple practical problems with it.
Content
This course first gives a comprehensive recap of Maxwell equations and important equations of electromagnetic field theory. In the second part the most important methods of numerical field calculation are introduced. Maxwell’s equations, materials equations, boundary conditions, fields in ferroelectric and ferromagnetic materials electric potentials, electric dipole, Coulomb integral, Laplace and Poisson’s equation, separation of variables in cartesian, cylindrical and spherical coordinates
Dirichlet Problem, Neumann Problem, Greens function, Field energy density and Poynting vector, electrostatic field energy, coefficients of capacitance, vector potential, Coulomb gauge, Biot-Savart-law, magnetic field energy, coefficients of inductance magnetic flux and coefficients of mutual inductance, field problems in steady electric currents, law of induction, displacement current general wave equation for E and H, Helmholtz equation skin effect, penetration depth, eddy currents retarded potentials, Coulomb integral with retarded potentials wave equation for potential and Vector potential and A, Lorentz gauge, plane waves Hertzian dipole, near field solution, far field solution transmission lines, fields in coaxial transmission lines waveguides, TM-waves, TE-waves finite difference method FDM finite difference - time domain FDTD, Yee’s algorithm finite difference - frequency domain finite integration method FIM finite element method FEM boundary element method BEM, Method of Moments (MOM), Transmission Line Matrix Methal (TLM), solving large systems of linear equations basic rules for good numerical field calculation The lecturer reserves the right to alter the contents of the course without prior notification.

Module grade calculation
The module grade is the grade of the written exam.

Workload
Each credit point corresponds to approximately 25-30 hours of work (of the student). This is based on the average student who achieves an average performance. The workload includes:
Attendance time in lectures (3 h 15 appointments each) = 45 h
Self-study (4 h 15 appointments each) = 60 h
Preparation / post-processing = 20 h
Total effort approx. 125 hours = 4 LP

Recommendation
Fundamentals of electromagnetic field theory.

Literature
Matthew Sadiku (2001), Numerical Techniques in Electromagnetics.
CRC Press, Boca Raton, 0-8493-1395-3
Allen Tafove and Susan Hagness (2000), Computational electrodynamics: the finite-difference time-domain method.
Artech House, Boston, 1-58053-076-1
Springer Verlag, New York, 0-387-94877-5
IOS Press, Ohmska, 1 58603 064 7
Module: Electronic Properties of Solids I, with Exercises [M-PHYS-102089]

**Responsible:** Prof. Dr. Matthieu Le Tacon  
Prof. Dr. Wolfgang Wernsdorfer  
Prof. Dr. Wulf Wulfhekel

**Organisation:** KIT Department of Physics  
**Part of:** Experimental Physics (Experimental Physics)

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**Mandatory**

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<tbody>
<tr>
<td>T-PHYS-102577</td>
<td>Electronic Properties of Solids I, with Exercises</td>
<td>10 CR</td>
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**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module **M-PHYS-102090 - Electronic Properties of Solids I, without Exercises** must not have been started.

**Competence Goal**

Students will be familiar with the most common experimental methods for studying the electronic properties of condensed matter and some of the key theoretical concepts that underlie them. They master the basic tools for studying and understanding heat transport, scattering mechanisms, phase transitions, and magnetism. Exercises will reinforce the acquired knowledge and apply it to classical condensed matter problems.

**Content**

- Metal and insulators: Band structure, Fermi surface  
- Electronic and heat transport - scattering mechanisms  
- Phase transitions: Landau theory, critical exponents  
- Atomic magnetism and magnetic interactions  
- Magnetic structures, dynamics

**Annotation**

The course will be given in English. Questions and discussions in German are welcome as well.

**Workload**

300 hours consisting of attendance time (75 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (225 hours)

**Recommendation**

Basic knowledge of solid state physics, quantum mechanics, and thermodynamics and statistical physics is assumed.

**Literature**

- R. Gross, A. Marx, Festkörperphysik  
- N. W. Ashcroft, N. D. Mermin: Festkörperphysik  
- H. Ibach, H. Lüth: Festkörperphysik  
- C. Kittel: Einführung in die Festkörperphysik  
- S. Blundell, Magnetism in Condensed Matter
2.52 Module: Electronic Properties of Solids I, without Exercises [M-PHYS-102090]

**Responsible:**
Prof. Dr. Matthieu Le Tacon
Prof. Dr. Wolfgang Wernsdorfer
Prof. Dr. Wulf Wulfhekel

**Organisation:**
KIT Department of Physics

**Part of:**
Experimental Physics (Experimental Physics)

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**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-PHYS-102089 - Electronic Properties of Solids I, with Exercises must not have been started.

**Competence Goal**

Students will be familiar with the most common experimental methods for studying the electronic properties of condensed matter and some of the key theoretical concepts that underlie them. They will master the basic tools for studying and understanding heat transport, scattering mechanisms, phase transitions, and magnetism.

**Content**

- Metal and insulators: Band structure, Fermi surface
- Electronic and heat transport - scattering mechanisms
- Phase transitions: Landau theory, critical exponents
- Atomic magnetism and magnetic interactions
- Magnetic structures, dynamics

**Annotation**

The course will be given in English. Questions and discussions in German are welcome as well.

**Workload**

240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation (180 hours)

**Recommendation**

Basic knowledge of solid state physics, quantum mechanics, and thermodynamics and statistical physics is assumed.

**Literature**

- R. Gross, A. Marx, Festkörperphysik
- N. W. Ashcroft, N. D. Mermin: Festkörperphysik
- H. Ibach, H. Lüth: Festkörperphysik
- C. Kittel: Einführung in die Festkörperphysik
- S. Blundell, Magnetism in Condensed Matter
Competence Certificate
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Prerequisites
none

Modeled Conditions
The following conditions have to be fulfilled:

1. The module M-PHYS-102109 - Electronic Properties of Solids II, without Exercises must not have been started.

Competence Goal
Students know the physical properties of superconductivity, a thermodynamic state of the electronic system of solids. They understand classical and modern experimental findings as well as basic theoretical models, such as the concept of the energy gap or the quasiparticle, which is also commonly used outside superconductivity. They apply the acquired knowledge to specific problems. The students are able to familiarize themselves with current literature on the subject of superconductivity.

Content
Foundations of superconductivity: thermodynamics, electrodynamics, flux quantization, Ginzburg-Landau theory, BCS theory, vortices, tunnel junctions, Josephson junctions, SQUIDs, superconducting electronics, superconducting qubits.

Annotation
The course will be given in English. Questions and discussions in German are welcome as well.

Workload
240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

Recommendation
Basic knowledge of solid state physics, quantum mechanics, and thermodynamics is assumed.

Literature

**Responsibility:**
- Prof. Dr. Matthieu Le Tacon
- Dr. Johannes Rotzinger
- Prof. Dr. Alexey Ustinov
- Prof. Dr. Wolfgang Wernsdorfer

**Organisation:**
- KIT Department of Physics
- Part of: Experimental Physics (Experimental Physics)

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**Mandatory**

| T-PHYS-104423 | Electronic Properties of Solids II, without Exercises | 4 CR | Le Tacon, Rotzinger, Ustinov, Wernsdorfer |

**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-PHYS-102108 - Electronic Properties of Solids II, with Exercises must not have been started.

**Competence Goal**

Students know the physical properties of superconductivity, a thermodynamic state of the electronic system of solids. They understand classical and modern experimental findings as well as basic theoretical models, such as the concept of the energy gap or the quasiparticle, which is also commonly used outside of superconductivity. Students are able to familiarize themselves with current literature on superconductivity.

**Content**

Foundations of superconductivity: thermodynamics, electrodynamics, flux quantization, Ginzburg-Landau theory, BCS theory, vortices, tunnel junctions, Josephson junctions, SQUIDs, superconducting electronics, superconducting qubits.

**Annotation**

The course will be given in English. Questions and discussions in German are welcome as well.

**Workload**

120 hours consisting of attendance time (30 hours), wrap-up of the lecture incl. exam preparation (90 hours)

**Recommendation**

Basic knowledge of solid state physics, quantum mechanics, and thermodynamics is assumed.

**Literature**

Module: Ergodic Theory [M-MATH-106473]

Responsible: Dr. Gabriele Link
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

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</table>

Competence Certificate

Oral examination of ca. 20-30 minutes.

Prerequisites

None

Competence Goal

Students

- know important examples of dynamical systems,
- can state and discuss substantial concepts of ergodic theory,
- can state important results on qualitative properties of dynamical systems and relate them,
- are prepared to read recent research articles and write a bachelor or master thesis in the field of ergodic theory.

Content

- Elementary examples of dynamical systems such as Bernoulli systems and billiards
- Poincare recurrence and ergodic theorems
- mixing, weak mixing, equidistribution
- entropy
- advanced topic(s) (as for example hyperbolic dynamics, symbolic dynamics and coding, Furstenberg correspondence principle or unitary representations of SL(2,R))

Module grade calculation

The grade of the module is the grade of the oral exam.

Workload

Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation

Some basic knowledge of measure theory, topology, geometry, group theory and functional analysis is recommended.
**2.56 Module: Evolution Equations [M-MATH-102872]**

**Responsible:** Prof. Dr. Roland Schnaubelt  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Analysis)  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

**Credits** 8  
**Grading scale** Grade to a tenth  
**Recurrence** see Annotations  
**Duration** 1 term  
**Language** German/English  
**Level** 4  
**Version** 1

**Mandatory**

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<td>T-MATH-105844</td>
<td>Evolution Equations</td>
<td>8 CR</td>
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</table>

**Competence Certificate**

Oral examination of ca. 30 minutes.

**Prerequisites**

none

**Competence Goal**

The students

- can explain the basics of the theory of strongly continuous operator semigroups and their generators, in particular the theorems on generation and wellposedness, and they can apply it to examples.  
- can also describe and use the solution and regularity theory of inhomogeneous Cauchy problems.  
- are able to construct analytic semigroups and to characterize their generators. Using these results and perturbations theorems, they can solve partial differential equations.  
- are able to explain main aspects of approximation theory of evolution equations.  
- can discuss the core statements of stability and spectral theory of operator semigroups and discuss examples by means of them.  
- have mastered the important techniques for proofs in evolution equations and are able to, at least, sketch the complicated proofs.

**Content**

- strongly continuous operator semigroups and their generators,  
- generation results and wellposedness,  
- inhomogeneous Cauchy problems,  
- analytic semigroups,  
- perturbation and approximation theory,  
- stability and spectral theory of operator semigroups,  
- applications to partial differential equations

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Annotation**

Regular cycle: every 2nd year. The module "Nonlinear Evolution Equations" is based on "Evolution Equations"
**Workload**
Total workload: 240 hours
Attendance: 90 h
- lectures, problem classes and examination

Self studies: 150 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**
The module “Functional Analysis” is strongly recommended.

**Literature**
K.-J. Engel und R. Nagel, One-Parameter Semigroups for Linear Evolution Equations.
Module: Exponential Integrators [M-MATH-103700]

2.57 Module: Exponential Integrators [M-MATH-103700]

Responsible: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

Credits 6
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Level 4
Version 1

Mandatory
T-MATH-107475 Exponential Integrators 6 CR Hochbruck, Jahnke

Competence Certificate
Oral exam of approximately 20 minutes

Prerequisites
None

Content
In this class we consider the construction, analysis, implementation and application of exponential integrators. The focus will be on two types of stiff problems.

The first one is characterized by a Jacobian that possesses eigenvalues with large negative real parts. Parabolic partial differential equations and their spatial discretization are typical examples. The second class consists of highly oscillatory problems with purely imaginary eigenvalues of large modulus.

Apart from motivating the construction of exponential integrators for various classes of problems, our main intention in this class is to present the mathematics behind these methods. We will derive error bounds that are independent of stiffness or highest frequencies in the system.

Since the implementation of exponential integrators requires the evaluation of the product of a matrix function with a vector, we will briefly discuss some possible approaches as well.
Module: Extremal Graph Theory [M-MATH-102957]

**Responsible:** Prof. Dr. Maria Aksenovich

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-105931 | Extremal Graph Theory | 4 CR | Aksenovich |

**Competence Certificate**
The final grade is given based on an oral exam (approx. 30 min.).

**Competence Goal**
The students understand, describe, and use fundamental notions and techniques in extremal graph theory. They can analyze, structure, and formally describe typical combinatorial questions. The students understand and use Szemerédi's regularity lemma and Szemerédi's theorem, can use probabilistic techniques, such as dependent random choice and multistep random colorings, know the best bounds for the extremal numbers of complete graphs, cycles, complete bipartite graphs, and bipartite graphs with bounded maximum degree. They understand and can use the Ramsey theorem for graphs and hypergraphs, as well as stepping-up techniques for bounding Ramsey numbers. Moreover, the students know and understand the behavior of Ramsey numbers for graphs with bounded maximum degree. The students can communicate using English technical terminology.

**Content**
The course is concerned with advanced topics in graph theory. It focuses on the areas of extremal functions, regularity, and Ramsey theory for graphs and hypergraphs. Further topics include Turán's theorem, Erdős-Stone theorem, Szemerédi's lemma, graph colorings and probabilistic techniques.

**Annotation**
Course is held in English

**Recommendation**
Basic knowledge of linear algebra, analysis and graph theory is recommended.
Module: Extreme Value Theory [M-MATH-102939]

**Responsible:** Prof. Dr. Vicky Fasen-Hartmann

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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</table>

**Competence Certificate**
The module will be completed by an oral exam (approx. 20 min).

**Prerequisites**
None

**Competence Goal**
Students are able to
- name, explain, motivate and apply statistical methods for estimating risk measures,
- model and quantify extreme events,
- apply specific probabilistic techniques of extreme value theory,
  - master proof techniques,
- work in a self-organised and reflective manner.

**Content**
- Theorem of Fisher and Tippett's
- Generalised extreme value and Pareto distribution (GED and GPD)
- Domain of attractions of generalised extreme value distributions
- Theorem of Pickands-Balkema-de Haan
- Estimation of risk measures
- Hill estimator
- Block maxima method
- POT method

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
Total workload: 120 hours
Attendance: 45 hours
  - lectures and problem classes including the examination.
Self studies: 75 hours
  - follow-up and deepening of the course content
  - work on problem sheets
  - literature and internet research on the course content
  - preparation for the module examination
Recommendation
The content of the module "Probability theory" is recommended.
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<td>Finite Element Methods</td>
<td>8 CR Dörfler, Hochbruck, Jahnke, Rieder, Wieners</td>
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# Module: Forecasting: Theory and Practice [M-MATH-102956]

**Responsible:** Prof. Dr. Tilmann Gneiting  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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<td><strong>Forecasting: Theory and Practice</strong></td>
<td>8 CR</td>
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**Prerequisites**

None

**Annotation**

- Regular cycle: every 2nd year, starting winter semester 16/17
- Course is held in English
## 2.62 Module: Formal Systems [M-INFO-100799]

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<th>Responsible:</th>
<th>Prof. Dr. Bernhard Beckert</th>
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Module: Foundations of Continuum Mechanics [M-MATH-103527]

**Responsible:** Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-107044 | Foundations of Continuum Mechanics | 3 CR | Wieners |

**Prerequisites**

none
Module: Fourier Analysis and its Applications to PDEs

Responsible: TT-Prof. Dr. Xian Liao
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
Mathematical Specialization (Elective Field Mathematical Specialization)

<table>
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Prerequisites
None
2.65 Module: Fractal Geometry [M-MATH-105649]

Responsible: PD Dr. Steffen Winter
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

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Mandatory

T-MATH-111296 Fractal Geometry 6 CR Winter

Competence Certificate
The module will be completed with an oral exam (20 - 30 min).

Prerequisites
None

Competence Goal

Students
- can name and explain important terms and concepts of fractal geometry;
- know important results of dimension theory and can apply them to examples;
- have the ability to use specific methods for the analysis of fractal structures;
- are able to construct fractals and random fractals with certain prescribed properties;
- master important proof techniques in fractal geometry and are able to at least sketch the more difficult proofs;
- are able to work self-organized and in a reflective manner;
- are prepared, to write a thesis in the field of fractal geometry.

Content
- iterated function systems and self-similar sets
- chaos game algorithm
- random fractals
- fractal dimension theory
- Hausdorff measure and dimension
- packing measure and dimension
- Minkowski contents
- methods of computing dimension
- self-similar measures and multifractals
- dimension of measures

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 h
- lectures, problem classes and examination
Self studies: 120 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination
Recommendation
The contents of the courses Analysis 3 (measure theory) and Probability theory are recommended.
Module: Functional Analysis [M-MATH-101320]

Responsible: Prof. Dr. Roland Schnaubelt
Organisation: KIT Department of Mathematics

Part of:
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits: 8
Grading scale: Grade to a tenth
Recurrence: Each winter term
Duration: 1 term
Level: 4
Version: 2

Mandatory

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<tr>
<td>T-MATH-102255</td>
<td>Functional Analysis</td>
<td>8 CR</td>
</tr>
</tbody>
</table>

Frey, Herzog, Hundertmark, Lamm, Liao, Reichel, Schnaubelt, Tolksdorf

Competence Certificate
Written examination of 120 minutes.

Prerequisites
None

Competence Goal
The students can

- explain basic topological concepts such as compactness in the framework of metric spaces, and are able to apply these in examples.
- describe the structure of Hilbert spaces and can use them in applications.
- explain the principle of uniform boundedness, the open mapping theorem and the Hahn-Banach theorem, and are able to derive conclusions from them.
- describe the concepts of dual Banach spaces, in particular weak convergence, reflexivity and the Banach-Alaoglu theorem. They can discuss these concepts in examples.
- explain the spectral theorem for compact self-adjoint operators.
- come up with a proof for simple functional analytic statements.

Content

- Metric spaces (basic topological concepts, compactness),
- Hilbert spaces, Orthonormal bases, Sobolev spaces,
- Continuous linear operators on Banach spaces (principle of uniform boundedness, open mapping theorem),
- Dual spaces and representations, Hahn-Banach theorem, Banach-Alaoglu theorem, weak convergence, reflexivity,
- Spectral theorem for compact self-adjoint operators.

Module grade calculation
The grade of the module is the grade of the written exam.

Workload
Total workload: 240 hours
Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination
Module: Functional Data Analysis [M-MATH-106485]

**Responsible:** Dr. rer. nat. Bruno Ebner

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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<td>T-MATH-113102</td>
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<td>4 CR</td>
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</table>

**Competence Certificate**

Oral examination of ca. 25 minutes.

**Prerequisites**

None

**Competence Goal**

The aim of the course is to give an introduction to weak convergence concepts in metric spaces and to highlight some statistical applications.

After successful participation students can

- model random elements in metric spaces,
- explain the concept of weak convergence in metric spaces and are familiar with structural problems in this context,
- apply limit laws for functionals of the empirical distribution function,
- model the normal distribution for random elements in Hilbert spaces,
- derive limit distributions of $L^2$ type goodness-of-fit statistics,
- apply goodness-of-fit tests to functional data.

**Content**

- Theorem of Glivenko-Cantelli,
- weak convergence in metric spaces,
- Theorem of Prokhorov,
- Gaussian Processes,
- Donsker's Theorem,
- functional central limit theorem,
- empirical processes,
- random elements in separable Hilbert spaces,
- Goodness-of-fit tests.

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 120 hours

**Attendance:**

- 45 h lectures and examination

**Self studies:**

- 75 h follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**

The contents of the modules "Probability Theory" and "Mathematical Statistics" are strongly recommended.
2.68 Module: Functions of Matrices [M-MATH-102937]

**Responsible:** PD Dr. Volker Grimm

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Competence Certificate**

The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**

none

**Competence Goal**

The students know the basic definitions and properties of matrix functions. They can evaluate methods for approximating matrix functions in terms of convergence and efficiency, independently solve exercises, present their own solutions and implement the methods discussed.

**Content**

- Definition of functions of matrices
- Approximations to functions of matrices for large sparse matrices
- Krylov subspace methods and rational Krylov subspace methods
- Application to the numerical solution of partial differential equations

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**

The courses Numerical Analysis 1 and 2 are strongly recommended.
2.69 Module: Functions of Operators [M-MATH-102936]

Responsible: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: 
  - Applied Mathematics (Elective Field Applied Mathematics)
  - Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 6
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Level 4
Version 1

Mandatory

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<td>Functions of Operators</td>
<td>6 CR</td>
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</table>

Competence Certificate
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
The students have basic knowledge of the approximation of functions of operators. They can examine the methods for convergence properties and efficiency. In the context of semigroups, they can analyze the procedures discussed, independently select the appropriate procedures and justify their choice.

Content
- Definition of functions of operators
- Strongly continuous and analytic semigroups
- Rational approximations to functions of operators with fixed poles
- Rational Krylov subspace method for the approximation of functions of operators
- Applications in the numerical analysis of semigroups

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 hours
- lectures, problem classes, and examination
Self-studies: 120 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The courses Numerical Analysis 1 and 2, and Functional Analysis are strongly recommended.
### Module: Fuzzy Sets [M-INFO-100839]

**Responsible:** Prof. Dr.-Ing. Uwe Hanebeck  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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Module: Generalized Regression Models [M-MATH-102906]

**Responsible:** PD Dr. Bernhard Klar  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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**Competence Certificate**  
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**  
None

**Competence Goal**  
At the end of the course, students will

- be familiar with the most important regression models and their properties,  
- be able to evaluate and interpret the results obtained using these models,  
- be able to use the models to analyze more complex data sets.

**Content**  
This course covers basic models of statistics that allow us to capture relationships between variables. Topics include

- Linear regression models:  
  - Model diagnostics  
  - Multicollinearity  
  - Variable selection  
  - Generalized least squares  
- Nonlinear regression models:  
  - Parameter estimation  
  - Asymptotic normality of maximum likelihood estimators  
- Regression models for count data  
- Generalized linear models:  
  - Parameter estimation  
  - Model diagnostics  
  - Overdispersion and quasi-likelihood

**Module grade calculation**  
The module grade is the grade of the oral exam.

**Workload**  
Total workload: 120 hours  
Attendance: 45 hours  
- lectures, problem classes, and examination  
Self-studies: 75 hours  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination
**Recommendation**

The contents of the course "Statistics" are strongly recommended.
2.72 Module: Geometric Analysis [M-MATH-102923]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-105892 | Geometric Analysis | 8 CR | Lamm |

**Prerequisites**

none
## M 2.73 Module: Geometric Group Theory [M-MATH-102867]

**Responsible:** Prof. Dr. Roman Sauer  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**  

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<th>Herrlich, Link, Llosa Isenrich, Sauer, Tuschmann</th>
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### 2.74 Module: Geometric Group Theory II [M-MATH-102869]

**Responsible:** Prof. Dr. Roman Sauer  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  

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</table>

**Prerequisites**

none
2.75 Module: Geometric Numerical Integration [M-MATH-102921]

- **Responsible:** Prof. Dr. Tobias Jahnke
- **Organisation:** KIT Department of Mathematics
- **Part of:**
  - Applied Mathematics (Elective Field Applied Mathematics)
  - Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**
- **Credits:** 6
- **Grading scale:** Grade to a tenth
- **Recurrence:** Irregular
- **Duration:** 1 term
- **Level:** 4
- **Version:** 1

**Mandatory**

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</table>

**Competence Certificate**
The module will be completed by an oral exam (about 20 min).

**Prerequisites**
none

**Competence Goal**
After attending the course, students understand the central properties of finite-dimensional Hamilton systems (energy conservation, symplectic flow, first integrals etc.). They know important classes of geometric time integrators such as, e.g., symplectic (partitioned) Runge-Kutta methods, splitting methods, SHAKE and RATTLE. They are not only able to implement these methods and apply them to practice-oriented problems, but also to analyze and explain the observed long-time behavior (e.g. approximative energy conservation over long times).

**Content**
- Newtonian equation of motion, Lagrange equations, Hamilton systems
- Properties of Hamilton systems: symplectic flow, energy conservation, other conserved quantities
- Symplectic numerical methods: symplectic Euler method, Störmer-Verlet method, symplectic (partitioned) Runge-Kutta methods
- Construction of symplectic methods, for example by composition and splitting
- Backward error analysis and energy conservation over long time intervals
- Mechanical systems with constraints

**Module grade calculation**
The module grade is the grade of the oral exam.

**Annotation**
The module is offered about every two years

**Workload**
Total workload: 180 hours

- **Attendance:** 60 hours
  - lectures, problem classes, and examination

- **Self-studies:** 120 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**
Familiarity with ordinary differential equations and Runge-Kutta methods (construction, order, stability, etc.) are strongly recommended. The course "Numerical methods for differential equations" provides an excellent basis. Moreover, programming skills in MATLAB are strongly recommended.
2.76 Module: Geometric Variational Problems [M-MATH-106667]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

<table>
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**Competence Certificate**

oral exam of ca. 30 min

**Prerequisites**

none

**Competence Goal**

The students

- can name basic results in the theory of geometric variational problems and relate them to each other;
- are prepared to write a thesis in the field of geometric analysis.

**Content**

- Harmonic maps
- Willmore surfaces
- Regularity theory
- Hardy and BMO spaces

**Module grade calculation**

The module grade is the grade of the oral examination.

**Workload**

Total workload: 240 hours

Attendance: 90 h

- lectures, problem classes and examination

Self studies: 150 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**

The modules *Classical Methods for Partial Differential Equations* and *Functional Analysis* are recommended.
2.77 Module: Geometry of Schemes [M-MATH-102866]

Responsible: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

<table>
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<td>1 term</td>
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</table>

Competence Certificate
The module is completed by an oral exam of about 30 minutes

Prerequisites
None

Competence Goal
At the end of the module, participants are able to

- relate the notion of algebraic schemes with that of algebraic varieties
- name and discuss basic properties of schemes
- deal with sheaves on schemes and investigate their properties
- start to read recent research papers in algebraic geometry and write a thesis in this field.

Content

- Sheaves of modules
- affine schemes
- varieties and schemes
- morphisms between schemes
- coherent and quasicoherent sheaves
- cohomology of sheaves

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total work load: 240 hours
Attendance: 90 hours
- lectures, problem classes and examination
Self studies: 150 hours
- follow-up and deepening of the course content
- work on problem sheets
- literature studies and internet research relating to the course content
- preparation for the module examination

Recommendation
The modules "Algebra" and "Algebraic Geometry" are strongly recommended.
### Module: Global Differential Geometry [M-MATH-102912]

**Responsible:** Prof. Dr. Wilderich Tuschmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

<table>
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<td>8 CR</td>
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**Prerequisites**

none
2.79 Module: Graph Theory [M-MATH-101336]

Responsible: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

<table>
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Competence Certificate
The final grade is given based on the written final exam (3h).
By successfully working on the problem sets, a bonus can be obtained. To obtain the bonus, one has to achieve 50% of the points on the solutions of the exercise sheets 1-6 and also of the exercise sheets 7-12. If the grade in the final written exam is between 4,0 and 1,3, then the bonus improves the grade by one step (0,3 or 0,4).

Prerequisites
None

Competence Goal
The students understand, describe and use fundamental notions and techniques in graph theory. They can represent the appropriate mathematical questions in terms of graphs and use the results such as Menger’s theorem, Kuratowski’s theorem, Turan’s theorem, as well as the developed proof ideas, to solve these problems. The students can analyze graphs in terms of their characteristics such as connectivity, planarity, and chromatic number. They are well positioned to understand graph theoretic methods and use them critically. Moreover, the students can communicate using English technical terminology.

Content
The course Graph Theory treats the fundamental properties of graphs, starting with basic ones introduced by Euler and including the modern results obtained in the last decade. The following topics are covered: structure of trees, paths, cycles and walks in graphs, minors, unavoidable subgraphs in dense graphs, planar graphs, graph coloring, Ramsey theory, and regularity in graphs.

Annotation
- Regular cycle: every 2nd year, winter semester
- Course is held in English
**2.80 Module: Group Actions in Riemannian Geometry [M-MATH-102954]**

**Responsible:** Prof. Dr. Wilderich Tuschmann

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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</table>

**Mandatory**

| T-MATH-105925 | Group Actions in Riemannian Geometry | 5 CR | Tuschmann |

**Prerequisites**

none
2.81 Module: Harmonic Analysis [M-MATH-105324]

**Responsibility:** Prof. Dr. Dorothee Frey

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

**Credits:** 8

**Grading scale:** Grade to a tenth

**Recurrence:** Irregular

**Duration:** 1 term

**Level:** 4

**Version:** 2

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**Mandatory**

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<tr>
<td></td>
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<td>Frey, Kunstmann, Schnaubelt, Tolksdorf</td>
</tr>
</tbody>
</table>

**Content**

- Fourier series
- Fourier transform on L1 and L2
- Tempered distributions and their Fourier transform
- Explicit solutions of the Heat-, Schrödinger- and Wave equation in Rn
- the Hilbert transform
- the interpolation theorem of Marcinkiewicz
- Singular integral operators
- the Fourier multiplier theorem of Mihlin
# 2.82 Module: Harmonic Analysis 2 [M-MATH-106486]

**Responsible:** Prof. Dr. Dorothee Frey  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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</table>

**Competence Certificate**

Oral examination of ca. 30 minutes.

**Prerequisites**

None

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 240 hours

- **Attendance:** 90 h  
  - lectures, problem classes and examination

- **Self studies:** 150 h  
  - follow-up and deepening of the course content,  
  - work on problem sheets,  
  - literature study and internet research on the course content,  
  - preparation for the module examination

**Recommendation**

The following modules are strongly recommended: "Harmonic Analysis", "Functional Analysis".
2.83 Module: Heat Transfer II [M-CIWVT-103051]

**Responsible:** Prof. Dr.-Ing. Thomas Wetzel

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

<table>
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**Mandatory**

| T-CIWVT-106067 | Heat Transfer II | 4 CR | Wetzel |

**Competence Certificate**
The examination is an oral examination with a duration of 20 minutes (section 4 subsection 2 number 2 SPO). Module grade is the grade of the oral examination.

**Prerequisites**
None

**Competence Goal**
Students can deduce the basic differential equations of thermofluidodynamics and know possible simplifications. They know different analytical and numerical solution methods for the transient temperature field equation in quiescent media and are able to use them actively. Students are able to apply these solution methods independently to other heat conduction problems such as the heat transfer in fins and needles.

**Content**
Advanced topics in heat transfer:
Thermo-fluid dynamic transport equations, transient heat conduction; thermal boundary conditions; analytical methods (combination and separation of variables, Laplace transform); numerical methods (finite difference and volume methods); heat transfer in fins and needles

**Module grade calculation**
The grade of the oral examination is the module grade.

**Workload**
- Attendance time (Lecture): 30 h
- Homework: 50 h
- Exam Preparation: 40 h

**Literature**
VDI-Wärmeatlas, Springer-VDI, 10. Auflage, 2011
2.84 Module: High Temperature Process Engineering [M-CIWVT-103075]

**Responsibility:** Prof. Dr.-Ing. Dieter Stapf

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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**Mandatory**

| T-CIWVT-106109 | High Temperature Process Engineering | 6 CR Stapf |

**Competence Certificate**

The examination is an oral examination with a duration of about 20 minutes (section 4 subsection 2 number 2 SPO).

**Prerequisites**

None

**Module grade calculation**

The grade of the oral examination is the module grade.

**Workload**

- Attendance time (Lecture): 45 h
- Homework: 75 h
- Exam Preparation: 60 h
### M 2.85 Module: Homotopy Theory [M-MATH-102959]

**Responsible:** Prof. Dr. Roman Sauer  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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Sauer
### 2.86 Module: Infinite dimensional dynamical systems [M-MATH-103544]

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<th>Responsible:</th>
<th>Prof. Dr. Jens Rottmann-Matthes</th>
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**Mandatory**

| T-MATH-107070 | Infinite dimensional dynamical systems | 4 CR | Rottmann-Matthes |

**Prerequisites**
None
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<th>5 CR</th>
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</table>
2.88 Module: Integral Equations [M-MATH-102874]

**Responsible:** PD Dr. Frank Hettlich

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

**Credits** 8  
**Grading scale** Grade to a tenth  
**Recurrence** Irregular  
**Duration** 1 term  
**Level** 4  
**Version** 1

### Mandatory

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**Mandatory**

- T-MATH-105834  Integral Equations  8 CR Arens, Griesmaier, Hettlich

**Competence Certificate**

The module will be completed by an oral exam (~30min.).

**Prerequisites**

none

**Competence Goal**

The students can clarify integral equations and can show existence and uniqueness of solutions by perturbation theory and by Fredholm theory. Ideas of proofs for Fredholm theory and perturbation theory especially in case of convolution equations can be described and explained. Furthermore, the students can formulate classical boundary value problems for ordinary differential equations and from potential theory in terms of integral equations.

**Content**

- Riesz and Fredholm theory
- Fredholm and Volterra integral equations
- Applications in potential theory
- Convolution equation

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

- Total workload: 240h
- Attendance: 90h
  - Lecture, problem class, examination
- Self studies: 150h
  - Follow-up and deepening of the course content
  - Work on problem sheets
  - Literature studies and internet research related to the course content
  - Preparation of the module examination
2.89 Module: Internet Seminar for Evolution Equations [M-MATH-102918]

**Responsible:** Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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### Mandatory

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</table>

**Competence Certificate**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
none

**Competence Goal**
Students can explain the basic ideas, concepts and statements of a sub-area of the theory of evolutionary equations and apply them to examples. They can work on this topic from a script and discuss it in a reading course.

**Content**
A part of the theory of evolution equations is introduced. The necessary basics (beyond the contents of an introductory lecture in functional analysis) are developed. The basic concepts, statements and methods of the respective subarea are treated systematically. Applications of the theory are discussed.

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Annotation**
The internet seminar has different main organizers each year, who send out a manuscript with exercises and provide a website with discussion forums. In Karlsruhe, the material is discussed in a two-hour reading course in the winter semester, which is roughly equivalent to a four-hour lecture with exercises. There is the opportunity (outside of our modules) to work on a project during the summer semester and present it at a final workshop in June. Further information and details on the current content can be found on Roland Schnaubelt's website, [http://www.math.kit.edu/iana3/~schnaubelt/en](http://www.math.kit.edu/iana3/~schnaubelt/en)

**Workload**
Total workload: 240 hours

- **Attendance:** 30 h
  - lectures and examination

- **Self studies:** 210 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination

**Recommendation**
The contents of the module "Functional Analysis" are strongly recommended.
Module: Internship [M-MATH-102861]

**Responsible:** Prof. Dr. Willy Dörfler  
PD Dr. Markus Neher

**Organisation:** KIT Department of Mathematics

**Part of:** Internship

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Mandatory

| T-MATH-105888 | Internship | 10 CR | Dörfler, Neher |

**Workload**

Gesamter Arbeitsaufwand: 300 Stunden.

Präsenzzeit: 270 Stunden im Unternehmen.

Selbststudium: 30 Stunden

- Ausarbeitung des Berichtes
- Vorbereitung und Halten der Präsentation
## 2.91 Module: Introduction into Particulate Flows [M-MATH-102943]

<table>
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<tr>
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<th>Prof. Dr. Willy Dörfler</th>
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### Prerequisites

none
2.92 Module: Introduction to Aperiodic Order [M-MATH-105331]

**Responsible:** Prof. Dr. Tobias Hartnick

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-110811 | Introduction to Aperiodic Order | 3 CR | Hartnick |

**Prerequisites**

None
Module: Introduction to Artificial Intelligence [M-INFO-106014]

**Responsible:** TT-Prof. Dr. Pascal Friederich
Prof. Dr. Gerhard Neumann

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

<table>
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**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-INFO-100819 - Cognitive Systems must not have been started.
2.94 Module: Introduction to Convex Integration [M-MATH-105964]

Responsible: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: 
Applied Mathematics (Analysis)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

<table>
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Mandatory
T-MATH-112119 Introduction to Convex Integration 3 CR Zillinger

Competence Certificate
The module will be completed with an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
The main aim of this lecture is to introduce students to convex integration as a tool to construct solutions to partial differential equations.
In particular, they will be able to

- discuss the structure of convex integration algorithms,
- state major theorems and their relation,
- discuss regularity of convex integration solutions and uniqueness,
- discuss building blocks of constructions and their properties.

Content
This lecture provides an introduction to the methods of convex integration and its applications:

- for isometric immersions,
- for the m-well problem in elasticity,
- for equations of fluid dynamics and
- higher regularity of convex integration solutions.

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 90 hours
Attendance: 30 h
- lectures and examination
Self studies: 60 h
- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The modules "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.
Module: Introduction to Cosmology [M-PHYS-102175]

**Mandatory**

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<th>Duration</th>
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<td>Each winter term</td>
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**Competence Certificate**

**Oral Exam.** In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Competence Goal**

Students will be introduced to the basic concepts of cosmology. The lecture will provide both the theoretical concepts and an overview of modern experimental methods and observational techniques. The students will be enabled to understand the concepts by means of concrete case studies from modern cosmology and will be enabled to apply the learned methods in the context of later independent research.

**Methodological Competency Acquisition:**

- Understanding of the fundamentals of cosmology
- Recognition of methodological cross-connections to elementary particle physics and astroparticle physics.
- Acquisition of the ability to work independently on current research topics as preparation for the master thesis.

**Content**

The lecture offers an introduction to modern cosmology, which has taken an enormous upswing in recent years due to the use of state-of-the-art technologies (Planck satellite, galaxy surveys such as 2dF and SDSS) and accompanying computationally intensive simulations (Millennium). The large number of observations has led to the establishment of a so-called concordance model of cosmology, in which the contributions of dark energy and dark matter dominate the evolution of large-scale structures in the universe.

Starting from a description of the early universe with the supporting pillars of the Big Bang theory (Hubble expansion, nucleosynthesis, cosmic background radiation) and the phase transitions and symmetry breaking that occur in the process, the formation and evolution of large-scale structures in the universe up to today's "dark universe" is discussed (comparison of "top-down" with "bottom-up" models). Special attention is given to a detailed presentation of the most modern experimental techniques and methods of analysis, which have found their way into wide areas of physics.

The lecture thus provides a coherent picture of modern cosmology and discusses fundamental issues also in neighboring disciplines such as particle physics and astrophysics and can therefore be complemented with other lectures in the field of Experimental Astroparticle Physics and Experimental Particle Physics.

**Workload**

180 hours consisting of attendance time (45 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (135 hours).

**Recommendation**

Basic knowledge from lecture "Nuclei and Particles"

**Literature**

Will be mentioned in the lecture.
### 2.96 Module: Introduction to Dynamical Systems [M-MATH-106591]

**Responsible:** Prof. Dr. Wolfgang Reichel  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

<table>
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**Mandatory**

| T-MATH-113263 | Introduction to Dynamical Systems | 6 CR | de Rijk, Reichel |

**Competence Certificate**
The module will be completed with an oral exam of about 30 minutes.

**Prerequisites**
None

**Competence Goal**
After successful completion of this module students

- can explain the significance of dynamical systems and give several examples;  
- have acquired miscellaneous tools to prove the existence of special solutions and to analyze the local dynamics around them;  
- master several techniques to describe global dynamics in certain classes of dynamical systems;  
- identify various bifurcations and explain how these change the dynamics of the system;  
- outline the main steps in establishing chaotic behavior.

**Content**

- Flows  
- Abstract dynamical systems  
- Lyapunov functions  
- Invariant sets  
- Limit sets and attractors  
- Hartman-Grobman theorem  
- Local (un)stable manifold theorem  
- Poincaré-Bendixson theorem  
- Periodic orbits and Floquet theory  
- Exponential dichotomies  
- Melnikov functions  
- Lin's method  
- Hamiltonian dynamics  
- Liénard systems  
- Bifurcations  
- Chaotic dynamics  
- (Introduction to) Fenichel theory  
- Center manifolds  
- Dynamical systems associated with semilinear evolution equations

**Module grade calculation**
The module grade is the grade of the oral exam.
**Workload**
Total workload: 180 hours

Attended: 60 h
- lectures, problem classes and examination

Self-studies: 120 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**
The following modules are strongly recommended: Analysis 1-2 and Linear Algebra 1-2. The module Analysis 4 is recommended.
2.97 Module: Introduction to Fluid Dynamics [M-MATH-105650]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

<table>
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**Mandatory**

| T-MATH-111297 | Introduction to Fluid Dynamics | 3 CR | Reichel |

**Competence Certificate**

The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**

None

**Competence Goal**

The main aim of this lecture is to introduce students to mathematical fluid dynamics. In particular, by the end of the course students will be able to

- discuss and explain the various formulations of the Euler equations and when these formulations are equivalent,
- state major theorems and their relation,
- discuss weak formulations, existence and uniqueness results.

**Content**

Mathematical description and analysis of fluid dynamics:

- physical motivation of the incompressible Euler and Navier-Stokes equations,
- Vorticity-Stream formulation and Eulerian and Lagrangian coordinates,
- Local existence theory and energy methods,
- Weak solutions and the Beale-Kato-Majda criterion.

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

Total workload: 90 hours

Attendance: 30 hours

- lectures, problem classes, and examination

Self-studies: 60 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**

The contents of the courses "Classical Methods for Partial Differential Equations" or "Boundary and Eigenvalue Problems" are recommended.
**Module: Introduction to Fluid Mechanics [M-MATH-106401]**

**Responsible:** TT-Prof. Dr. Xian Liao  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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<td>Introduction to Fluid Mechanics</td>
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</table>

**Competence Certificate**
The module examination takes the form of an oral examination of approx. 25 minutes.

**Prerequisites**
None

**Competence Goal**
Graduates can

- recognize the essential formulations of the partial differential equations in fluid mechanics and explain them using examples,
- use techniques to describe the weak and strong solutions for the Euler and Navier-Stokes equations, and show the existence, uniqueness and regularity results,
- name the special difficulties in the three-dimensional case,
- understand the concept of stratification and explain it using concrete examples.

**Content**

- Derivation of models, modeling
- Euler equations, Navier-Stokes equations
- Biot-Savart law, Leray-Hopf decomposition
- Wellposedness results
- Regularity results

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total work load: 180 hours

**Recommendation**
The module *Functional Analysis* is strongly recommended.
Module: Introduction to Geometric Measure Theory [M-MATH-102949]

Responsible: PD Dr. Steffen Winter
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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Prerequisites
none
Module: Introduction to Homogeneous Dynamics [M-MATH-105101]

**Responsible:** Prof. Dr. Tobias Hartnick

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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<td>Introduction to Homogeneous Dynamics</td>
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**Prerequisites**

None
Module: Introduction to Kinetic Equations [M-MATH-105837]

Responsible: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits: 3
Grading scale: Grade to a tenth
Recurrence: Irregular
Duration: 1 term
Language: English
Level: 4
Version: 2

Mandatory

| T-MATH-111721 | Introduction to Kinetic Equations | 3 CR | Zillinger |

Competence Certificate
oral examination of approx. 30 minutes

Prerequisites
none

Competence Goal
The main aim of this lecture is to introduce students to the theory of kinetic transport equations. In particular, by the end of the course students will be able to

- discuss properties of the free transport, Boltzmann and Vlasov-Poisson equations,
- state major theorems and their relation,
- discuss notions of solutions and their properties,
- discuss the effects of phase mixing and challenges of nonlinear equations.

Content
Mathematical description and analysis of kinetic transport equations:

- the free transport, Boltzmann and Vlasov-Poisson equations,
- linear theory, phase mixing and Landau damping,
- equilibrium solutions and stability,
- nonlinear results and methods,
- renormalized solutions.

Module grade calculation
The module grade is the grade of the final oral exam.

Workload
Total workload: 90 h
Attendance: 30 h

- lectures and examination

Self studies: 60 h

- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The contents of the course "Classical Methods for Partial Differential Equations" are recommended.
2.102 Module: Introduction to Kinetic Theory [M-MATH-103919]

**Responsible:** Prof. Dr. Martin Frank

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-108013 | Introduction to Kinetic Theory | 4 CR | Frank |

**Prerequisites**
None

**Competence Goal**
After successfully taking part in the module’s classes and exams, students have gained knowledge and abilities as described in the “Inhalt” section. Specifically, Students know common means of mesoscopic and macroscopic description of particle systems. Furthermore, students are able to describe the basics of multiscale methods, such as the asymptotic analysis and the method of moments. Students are able to apply numerical methods to solve engineering problems related to particle systems. They can name the assumptions that are needed to be made in the process. Students can judge whether specific models are applicable to the specific problem and discuss their results with specialists and colleagues.

**Content**

- From Newton's equations to Boltzmann's equation
- Rigorous derivation of the linear Boltzmann equation
- Properties of kinetic equations (existence & uniqueness, H theorem)
- The diffusion limit
- From Boltzmann to Euler & Navier-Stokes
- Method of Moments
- Closure techniques
- Selected numerical methods

**Recommendation**

Partial Differential Equations, Functional Analysis
Module: Introduction to Microlocal Analysis [M-MATH-105838]

Responsible: TT-Prof. Dr. Xian Liao
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

<table>
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<tr>
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Competence Certificate
oral examination of circa 30 minutes

Prerequisites
none

Competence Goal
- Students will become familiar with the notions of Fourier multipliers and pseudo-differential operators
- Students can state major theorems and their relation
- Students will understand the structure of the propagation of singularities by introducing the wave front set and apply them to the domain of partial differential equations, control theory, etc.

Content
1. Pseudo-differential operators
2. Symbolic calculus
3. Wavefront set
4. Propagation of singularities
5. Microlocal defective measure

Module grade calculation
The module grade is the grade of the final oral exam.

Workload
Total workload: 90 h
Attendance: 30 h
- lectures and examination
Self studies: 60 h
- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The following courses should be studied beforehand: "Classical Methods for Partial Differential Equations" und "Functional Analysis".
Module: Introduction to Scientific Computing [M-MATH-102889]

**Responsible:**
Prof. Dr. Willy Dörfler
Prof. Dr. Tobias Jahnke

**Organisation:**
KIT Department of Mathematics

**Part of:**
Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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</table>

**Mandatory**

| T-MATH-105837 | Introduction to Scientific Computing | 8 CR | Dörfler, Hochbruck, Jahnke, Rieder, Wieners |

**Competence Certificate**
The module will be completed by an oral exam (about 30 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students

- are able to develop the interlinking of all aspects of scientific computing using simple examples: from modeling and algorithmic implementation to stability and error analysis.
- can explain concepts of modeling with differential equations
- are able to implement simple application examples algorithmically, evaluate the code and present and discuss the results.

**Content**

- Numerical methods for initial value problems, boundary value problems, and initial boundary value problems
- Modelling with differential equations
- Algorithmic realization of applications
- Presentation of results of scientific computations

**Module grade calculation**
The module grade is the grade of the oral exam.

**Annotation**
3 SWS lecture plus 3 SWS hands-on training

**Workload**
Total workload: 240 hours

- **Attendance:** 90 hours
  - lectures, problem classes, and examination
- **Self-studies:** 150 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination
Recommendation
It is strongly recommended that participants have completed the modules "Numerische Mathematik 1 und 2" as well as "Programmieren: Einstieg in die Informatik und algorithmische Mathematik".
Module: Introduction to Stochastic Differential Equations [M-MATH-106045]

Responsible: Prof. Dr. Mathias Trabs
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits 4
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Language English
Level 4
Version 1

Competence Certificate
The module will be completed with an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
The students will

- know fundamental examples for linear and non-linear stochastic differential equations,
- be able to apply basic solution concepts for stochastic differential equations,
- know fundamental theorems of stochastic calculus and will be able to apply these to stochastic differential equations.

Content
1. Introduction and recapitulation of stochastic integration, Itô's formula, Lévy Theorem
2. Burkholder-Davis-Gundy inequality
3. Existence and uniqueness of solutions of stochastic differential equations
4. Explicit solutions of linear stochastic differential equations
5. Change of the time scale of Brownian motion
6. Representation of continuous time martingales
7. Brownian martingales
8. Local and global solutions of stochastic differential equations
9. Girsanov Theorem

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours
Attendance: 45 hours
- lectures, problem classes, and examination
Self-studies: 75 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The contents of the course "Probability Theory" are strongly recommended. The contents of the course "Continuous Time Finance" are recommended.
### 2.106 Module: Inverse Problems [M-MATH-102890]

**Responsible:** Prof. Dr. Roland Griesmaier  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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#### Mandatory

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<td>Arens, Griesmaier, Hettlich, Rieder</td>
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#### Competence Certificate

The module will be completed by an oral exam (approx. 30 min).

#### Prerequisites

None

#### Competence Goal

At the end of the course, students are able to distinguish well-posed from ill-posed problems. They acquire a systematic knowledge of the theory of linear inverse problems and their regularization in Hilbert spaces and can provide proof ideas. They are able to analyze regularization methods such as, e.g., Tikhonov regularization and assess their convergence properties.

#### Content

- Compact operator equations  
- Ill-posed problems  
- Regularization  
- Tikhonov regularization  
- Iterative regularization  
- Examples for ill-posed problems

#### Module grade calculation

The module grade is the grade of the oral exam.

#### Workload

- **Total workload:** 240 hours  
- **Attendance:** 90 hours  
  - lectures, problem classes, and examination  
- **Self-studies:** 150 hours  
  - follow-up and deepening of the course content,  
  - work on problem sheets,  
  - literature study and internet research relating to the course content,  
  - preparation for the module examination

#### Recommendation

The course "Functional Analysis" or "Integral Equations" is recommended as a prerequisite.
2.107 Module: IT Security [M-INFO-106315]

Responsible:
Prof. Dr. Hannes Hartenstein
Prof. Dr. Jörn Müller-Quade
Prof. Dr. Thorsten Strufe
TT-Prof. Dr. Christian Wressnegger

Organisation:
KIT Department of Informatics

Part of:
Computer Science

Credits
6

Grading scale
Grade to a tenth

Recurrence
Each winter term

Duration
1 term

Language
German/English

Level
4

Version
2

Mandatory

| T-INFO-112818 | IT Security | 6 CR | Hartenstein, Müller-Quade, Strufe, Wressnegger |

Competence Certificate
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students
• have in-depth knowledge of cryptography and IT security
• know and understands sophisticated techniques and security primitives to achieve the protection goals
• know and understand scientific evaluation and analysis methods of IT security (game-based formalization of confidentiality and integrity, security and anonymity notions)
• have a good understanding of types of data, personal data, legal and technical fundamentals of privacy protection
• know and understand the fundamentals of system security (buffer overflow, return-oriented programming, ...) and can assess their effectivity

Content
Based on the content of the compulsory lecture "Informationssicherheit", this module deepens different topics of IT security. These include in particular:
• Elliptic curve cryptography
• Threshold cryptography
• Zero-knowledge proofs
• Secret sharing
• Secure multi-party computation and homomorphic encryption
• Methods of IT security (game-based analysis and the UC model)
• Crypto-currencies and consensus through proof-of-work/stake
• Anonymity on the Internet, anonymity with online payments
• Privacy-preserving machine learning
• Security of machine learning
• System security and exploits
• Threat modeling and quantification of IT security

Workload
Course workload:
1. Attendance time: 56 h
2. Self-study: 56 h
3. Preparation for the exam: 68 h

Recommendation
Students should be familiar with the content of the compulsory lecture "Informationssicherheit".
Literature

Literature:
- Katz/Lindell: Introduction to Modern Cryptography (Chapman & Hall)
- Schäfer/Roßberg: Netzsicherheit (dpunkt)
- Anderson: Security Engineering (Wiley, and online)
- Stallings/Brown: Computer Security (Pearson)
- Pfleeger, Pfleeger, Margulies: Security in Computing (Prentice Hall)
### Module: Key Competences [M-MATH-102994]

**Organisation:** KIT Department of Mathematics  
**Part of:** Interdisciplinary Qualifications

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**Election notes**  
For self assignment of taken interdisciplinary qualifications of HoC, ZAK or SPZ the 'Teilleistungen' with the title "Self Assignment HoC-ZAK-SPZ ..." have to be selected according to the grading scale, not graded or graded.

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**Prerequisites**  
None
Module: Key Moments in Geometry [M-MATH-104057]

**Responsible:** Prof. Dr. Wilderich Tuschmann

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Prerequisites**

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**Prerequisites**

none
# 2.111 Module: Lie Groups and Lie Algebras [M-MATH-104261]

**Responsible:** Prof. Dr. Tobias Hartnick  
**Organisation:** KIT Department of Mathematics

**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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### 2.112 Module: Lie-Algebras (Linear Algebra 3) [M-MATH-105839]

**Responsible:** Prof. Dr. Tobias Hartnick  
**Organisation:** KIT Department of Mathematics  
**Part of:** Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

<table>
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**Mandatory**

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<td>Lie-Algebras (Linear Algebra 3)</td>
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<td>Localization of Mobile Agents</td>
<td>6 CR</td>
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</table>
Module: Markov Decision Processes [M-MATH-102907]

**Responsible:** Prof. Dr. Nicole Bäuerle

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

<table>
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<td>Markov Decision Processes</td>
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</table>

**Competence Certificate**
The module will be completed by an oral exam (about 20 min).

**Prerequisites**
none

**Competence Goal**
At the end of the course, students

- can name the mathematical foundations of Markov Decision Processes and apply solution algorithm,
- can formulate stochastic, dynamic optimization problems as Markov Decision Processes,
- are able to work in a self-organized and reflective manner.

**Content**

- MDPs with finite time horizon
  - Bellman equation
  - Problems with structure
  - Applications
- MDPs with infinite time horizon
  - contracting MDPs
  - positive MDPs
  - Howards policy improvement
  - Solution by linear programs
- Stopping problems
  - finite and infinite time horizon
  - One-step-look-ahead rule

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 150 hours

- Attendance: 60 hours
  - lectures, problem classes, and examination
- Self-studies: 90 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**
The course 'Probability theory' is strongly recommended and 'Markov chains' is recommended.
2.115 Module: Master's Thesis [M-MATH-102917]

**Responsible:** PD Dr. Stefan Kühnlein  
**Organisation:** KIT Department of Mathematics  
**Part of:** Master's Thesis

<table>
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<th>Credits</th>
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<th>Duration</th>
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<td>1 term</td>
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</table>

### Competence Certificate
The Master's Thesis is graded according to the regulations from §14 (7) of Studien- und Prüfungsordnung. The handling time is six months. On submission of the Master's Thesis, according to §14 (5) the students have to confirm, that the thesis has been written independently without using undisclosed sources and tools, that passages which have been copied literally or in content have clearly been marked as such, and that the by-laws to implement scientific integrity at KIT in the recent version have been taken into account. If this confirmation is not contained, the thesis gets rejected. In case of a wrong confirmation, the thesis is graded with "not sufficient" (5.0). The thesis may be written in English.

If the thesis is planned to be written outside the KIT-department of mathematics, the approval by the examination board is required.

Further details are regulated by §14 of Studien- und Prüfungsordnung.

### Prerequisites
For admission to the module Master's Thesis it is required that the student has successfully accomplished module examinations of at least 70 credit points.

### Modeled Conditions
The following conditions have to be fulfilled:

1. You need to have earned at least 70 credits in the following fields:
   - Wildcard Technical Field
   - Applied Mathematics
   - Internship
   - Chemical and Process Engineering
   - Electrical Engineering / Information Technology
   - Experimental Physics
   - Computer Science
   - Mathematical Specialization
   - Interdisciplinary Qualifications

### Competence Goal
The students are able to work on a given topic independently and in a limited time, using scientific methods from the state of the art. They master the necessary scientific methods and techniques, modify them if necessary and develop them further if required. Alternative approaches are compared critically. In their thesis, the students write up their results clearly structured and in a way adequate to academic standards.

### Content
Following §14 SPO the thesis should demonstrate that the students are able to work on a given topic from their course of studies independently and in a bounded time, using scientific methods from the state of the art. The students should have the opportunity to make suggestions for their topic. If the student petitions, in exceptional cases the head of the examination board takes care that the student receives a topic for a master thesis within four weeks. In that case, the topic is given by the head of the examination board. Further details are regulated by §14 of Studien- und Prüfungsordnung.

### Workload
Total work load: 900 hours

Attendance: 0 hours
Self studies: 900 hours
Module: Mathematical Methods in Signal and Image Processing [M-MATH-102897]

Responsible: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics

Part of:
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

<table>
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<td>1 term</td>
<td>4</td>
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</table>

Competence Certificate
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
none

Competence Goal
Graduates know the essential mathematical tools of signal and image processing and their properties. They are able to apply these tools appropriately and to scrutinize and evaluate the results obtained.

Content
- Digital and analog systems
- Integral Fourier transform
- Sampling and resolution
- Discrete and fast Fourier transform
- Non-uniform sampling
- Anisotropic diffusion filters
- Variational methods

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classes, and examination
Self-studies: 150 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The course “Functional analysis” is recommended.
Module: Mathematical Methods of Imaging [M-MATH-103260]

Responsible: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits: 5
Grading scale: Grade to a tenth
Recurrence: Irregular
Duration: 1 term
Level: 4
Version: 1

Competence Certificate
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
None

Competence Goal
Graduates become familiar with some imaging methods and are able to discuss and analyze the underlying mathematical aspects. In particular, they will be able to explain the functional-analytical properties of the imaging operators. They can implement the corresponding reconstruction algorithms and they can explain and evaluate the artifacts that appear. They are able to apply the techniques they have learned to related problems.

Content
- Variants of tomography (X-ray, impedance, seismic, etc.)
- Properties of (generalized) Radon transforms
- Microlocal analysis/Pseudodifferential operators
- Ill-Posedness and regularization
- Reconstruction algorithms

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total work load: 150 hours
Attendance: 60 hours
- lectures, problem classes, and examination
Self-studies: 90 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The course „Functional Analysis“ is recommended.
## 2.118 Module: Mathematical Modelling and Simulation in Practise [M-MATH-102929]

**Responsible:** PD Dr. Gudrun Thäter  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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</table>

**Competence Certificate**  
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**  
None

**Competence Goal**  
The general aim of this lecture course is threefold:  
1) to interconnect different mathematical fields,  
2) to connect mathematics and real life problems,  
3) to learn to be critical and to ask relevant questions.  

At the end of the course, students can  
- work Project-orientated,  
- link knowledge from different fields,  
- develop typical modelling approaches on their own.

**Content**  
Mathematical thinking (as modelling) and mathematical techniques (as tools) meet application problems such as:  
- Differential equations  
- Population models  
- Traffic flow  
- Game theory  
- Chaos  
- Mechanics and fluids

**Module grade calculation**  
The module grade is the grade of the oral exam.

**Annotation**  
The lecture is always in English.  
To earn the credits you have to attend the lecture, finish the work on one project during the term in a group of 2-3 persons and pass the exam. The topic of the project is up to the choice of each group.
Workload
Total workload: 120 hours
Attendance: 45 hours
  • lectures, problem classes, and examination
  • Project presentations
Self-studies: 75 hours
  • follow-up and deepening of the course content,
  • work on problem sheets,
  • literature study and internet research relating to the course content,
  • preparation for the module examination,
  • work on the project

Recommendation
Some basic knowledge of numerical mathematics is recommended.

Literature
### 2.119 Module: Mathematical Statistics [M-MATH-102909]

**Responsible:** PD Dr. Bernhard Klar  
Prof. Dr. Mathias Trabs  

**Organisation:** KIT Department of Mathematics  

**Part of:**  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  

**Additional Examinations**

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<td>Each winter term</td>
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**Competence Certificate**  
The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**  
none

**Competence Goal**  
By the end of the course, students will

- know the basic concepts of mathematical statistics,
- be able to apply them independently to simple problems and examples,
- know specific probabilistic techniques and be able to use them for the mathematical analysis of estimation and test procedures,
- know the asymptotic behavior of maximum likelihood estimators and the generalized likelihood ratio for parametric test problems.

**Content**  
The course covers basic concepts of mathematical statistics, in particular the finite optimality theory of estimators and tests, and the asymptotic behavior of estimators and test statistics. Topics are:

- Optimal and best linear unbiased estimators,
- Cramér-Rao bound in exponential families,
- sufficiency, completeness and the Lehmann-Scheffé theorem,
- the multivariate normal distribution,
- convergence in distribution and multivariate central limit theorem,
- Glivenko-Cantelli theorem,
- limit theorems for U-statistics,
- asymptotic estimation theory (maximum likelihood estimator),
- asymptotic relative efficiency of estimators,
- Neyman-Pearson tests and optimal unbiased tests,
- asymptotic tests in parametric models (likelihood ratio tests).

**Module grade calculation**  
The module grade is the grade of the oral exam.
**Workload**

Total workload: 240 hours

Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**

The contents of the courses "Probability theory" and "Statistics" are strongly recommended.
2 MODULES

Module: Mathematical Topics in Kinetic Theory [M-MATH-104059]

2.120 Module: Mathematical Topics in Kinetic Theory [M-MATH-104059]

Responsible: Prof. Dr. Dirk Hundertmark
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

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Mandatory

| T-MATH-108403 | Mathematical Topics in Kinetic Theory | 4 CR | Hundertmark |

Prerequisites
None

Competence Goal
The students are familiar with the basic questions in kinetic theory and methodical approaches to their solutions. With the acquired knowledge they are able to understand the required analytical methods and are able to apply them to the basic equations in kinetic theory.

Content
- Boltzmann equation: Cauchy problem and properties of solutions
- entropy and H theorem
- equilibrium and convergence to equilibrium
- other models of kinetic theory
2.121 Module: Maxwell's Equations [M-MATH-102885]

Responsible: PD Dr. Frank Hettlich

Organisation: KIT Department of Mathematics

Part of: Applied Mathematics (Analysis)
Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

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Mandatory

| T-MATH-105856 | Maxwell's Equations | 8 CR | Arens, Griesmaier, Hettlich |

Competence Certificate
The module will be completed by an oral exam (~30min.).

Prerequisites
none

Competence Goal
The students can explain mathematical questions from the theory of Maxwell's equations. They can formulate and prove the main theorems on properties and existence of solutions, can apply these to specific cases, and can compare results with simpler differential equations (like the Helmholtz equation).

Content
Specific examples of solutions to Maxwell's equations, properties of solutions (e.g. representation theorems), specific cases like E-mode and H-mode, corresponding boundary value problems.

Module grade calculation
The module grade is the grade of the oral exam

Workload
Total workload: 240h

Attendance: 90h
- lecture, problem class, examination

Self-Studies: 150h
- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research related to the course content
- preparation of the course content

Recommendation
Desirable is basic knowledge from functional analysis
Module: Medical Imaging Technology I [M-ETIT-106449]

**Responsible:** Prof. Dr.-Ing. Maria Francesca Spadea

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

<table>
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**Mandatory**

| T-ETIT-113048 | Medical Imaging Technology I | 3 CR | Spadea |

**Competence Certificate**

The examination takes place in form of a written examination lasting 60 minutes.

**Prerequisites**

none

**Competence Goal**

For each imaging modality students will be able to:

- identify required energy source;
- analyze the interactions between the form of energy and biological tissue distinguishing desired signal from noise contribution;
- critically interpret the image content to derive knowledge
- evaluate image quality and implementing strategies to improve it.

Moreover, the students will be able to communicate in technical and clinical English language.

**Content**

The module Medical Imaging Technology I provides knowledge on

- the basic knowledge of mathematical and physical principles of medical imaging formation, including X-ray based modalities, nuclear medicine imaging, magnetic resonance imaging and ultrasound
- the component of medical imaging devices.
- assessment of image quality in terms of signal-to-noise-ratio, presence of artifact, spatial, spectral and temporal resolution
- safety and protection for patients and workers.

**Module grade calculation**

The module grade is the grade of the written exam.

**Workload**

1. attendance in lectures an exercises: 2SWS = 30 h
2. preparation / follow-up: 15*2 h = 30 h
3. preparation of and attendance in examination: 30 h

A total of 90 h = 3 CR

**Recommendation**

Basic knowledge in the field of physics and signal processing is helpful.
Module: Medical Imaging Technology II [M-ETIT-106670]

**Responsible:** Prof. Dr.-Ing. Maria Francesca Spadea

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

**Credits:** 3

**Grading scale:** Grade to a tenth

**Recurrence:** Each summer term

**Duration:** 1 term

**Language:** English

**Level:** 4

**Version:** 1

**Mandatory**

<table>
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<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>T-ETIT-113421</td>
<td>Medical Imaging Technology II</td>
<td>3 CR</td>
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</tbody>
</table>

**Spadea**

**Competence Certificate**
The examination takes place in form of a written examination lasting 60 minutes.

**Prerequisites**
none

**Competence Goal**
For each imaging modality students will be able to:

- identify required energy source;
- analyze the interactions between the form of energy and biological tissue;
- distinguishing desired signal from noise contribution;
- critically interpret the image content to derive knowledge;
- evaluate image quality and implementing strategies to improve it.

Moreover, the student will be able to communicate in technical and clinical English language.

**Content**

- the basic knowledge of mathematical and physical principles of medical imaging formation, including nuclear medicine imaging and magnetic resonance imaging;
- the component of medical imaging devices;
- assessment of image quality in terms of signal-to-noise-ratio, presence of artifact, spatial, spectral and temporal resolution;
- safety and protection for patients and workers.

**Module grade calculation**
The module grade is the grade of the written exam.

**Workload**

- attendance in class: 15*2h = 30h
- preparation / follow-up: 15*2h = 30h
- exam preparation / attendance: 30h = 90h

A total of 90h = 3 CR

**Recommendation**

- Basic knowledge in the field of physics and signal processing is helpful.
- The contents of the module "Medical Imaging Technology I" are recommended.
## 2.124 Module: Methods of Signal Processing [M-ETIT-100540]

<table>
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<th>Duration</th>
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**Responsible:** Prof. Dr.-Ing. Michael Heizmann  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

### Mandatory

<table>
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**Prerequisites**

none
Module: Metric Geometry [M-MATH-105931]

Responsible: Prof. Dr. Alexander Lytchak
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

<table>
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<th>Credits</th>
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Mandatory

T-MATH-111933 Metric Geometry 8 CR Lytchak, Nepechiy

Competence Certificate
oral examination of circa 20 minutes

Prerequisites
None

Module grade calculation
The module grade is the grade of the final oral exam.
2.126 Module: Minimal Surfaces [M-MATH-106666]

### Responsible
Dr. Peter Lewintan

### Organisation
KIT Department of Mathematics

### Part of:
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

### Credits
3

### Grading scale
Grade to a tenth

### Recurrence
Irregular

### Duration
1 term

### Language
German

### Level
4

### Version
1

### Mandatory
| T-MATH-113417 | Minimal Surfaces | 3 CR | Lewintan |

### Competence Certificate
The module will be completed by an oral exam (about 30 min).

### Prerequisites
None

### Competence Goal
Graduates

- are able to mathematically understand and solve a practical problem;
- can explain important results of the theory of minimal surfaces and apply them to examples;
- are prepared to write a thesis in the field of the theory of minimal surfaces or the calculus of variations.

### Content
Minimal surfaces are critical points of the area functional and locally minimize its area. They can also be described by having zero mean curvature. In this course we consider two dimensional minimal surfaces in $\mathbb{R}^3$ and discuss their properties. We will use arguments from differential geometry, the calculus of variations, the theory of partial differential equations and functions of a complex variable. Our goal is to prove the classical Plateau's problem.

### Module grade calculation
The module grade is the grade of the oral exam.

### Workload
Total workload: 90 hours

- Attendance: 30 hours
  - lectures, problem classes, and examination

- Self-studies: 60 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

### Recommendation
The course "Classical Methods for Partial Differential Equations" is recommended.
2.127 Module: Modelling and Simulation of Lithium-Ion Batteries [M-MATH-106640]

**Responsible:** Prof. Dr. Willy Dörfler

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

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<td>Modelling and Simulation of Lithium-Ion Batteries</td>
<td>4 CR</td>
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</table>

**Competence Certificate**

oral exam of ca. 20 minutes

**Prerequisites**

None

**Competence Goal**

Participants know about the modelling and physical basics that lead to the model equations. They can explain (at least for simplified problems) their well-posedness. They are able to analyze stability and convergence of the presented methods.

**Content**

- Derivation of the model equations,
- Existence for simplified model problems,
- Discretization of the initial boundary value problems with finite elements,
- Nonlinear diffusion equations, Cahn-Hilliard equation, linear elasticity and contact problems,
- Stability and convergence of the discrete models,
- Applications

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 120 hours

Attendance: 45 h

- lectures, problem classes and examination

Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**

Basic knowledge in the numerical treatment of differential equations, such as boundary value problems or initial value problems is strongly recommended.
Module: Models of Mathematical Physics [M-MATH-102875]

Responsible: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
          Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)

Mandatory

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</table>

Hundertmark, Plum, Reichel

Competition Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None

Competence Goal
Graduates will be able to
- understand the modeling of fundamental physical effects,
- understand the most important mathematical properties of these differential equation models,
- calculate exemplary solutions,
- draw conclusions regarding the models from the provable properties of the differential equations and the solutions.

Content
- Reaction-diffusion models
- Wave phenomena
- Maxwell equations and electrodynamics
- Schrödinger equation and quantum mechanics
- Navier-Stokes equation and fluid dynamics
- Elasticity
- Surface tension

Module grade calculation
The module grade is the grade of the oral/written exam.

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classes, and examination
Self-studies: 150 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination
2.129 Module: Modern Experimental Physics I, Atoms, Nuclei and Molecules [M-PHYS-106331]

**Responsible:** Studiendekan Physik  
**Organisation:** KIT Department of Physics  
**Part of:** Experimental Physics (Experimental Physics)

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**Mandatory**

| T-PHYS-112846 | Modern Experimental Physics I, Atoms, Nuclei and Molecules | 8 CR | Studiendekan Physik |

**Competence Certificate**

See components of this module

**Prerequisites**

none
2.130 Module: Modern Experimental Physics II, Structure of Matter [M-PHYS-106332]

**Responsible:** Studiendekan Physik

**Organisation:** KIT Department of Physics

**Part of:** Experimental Physics (Experimental Physics)

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**Competence Certificate**

See components of this module

**Prerequisites**

none
2.131 Module: Modular Forms [M-MATH-102868]

Responsible: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits 8
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Level 4
Version 1

Competence Certificate
The exam is an oral exam of about 30 minutes.

Prerequisites
None

Competence Goal
Participants are able to

- understand basic questions discussed in the theory of modular forms
- see the relevance of analytic results for solving certain arithmetic problems
- start reading a recent research paper and write a thesis in the area of modular forms.

Content
- Modular Group: Upper half plane, Mobius transforms, fundamental regions, Eisenstein series, modular forms, dimension formula
- congruence subgroups: Petersson scalar product, Hecke operators, Atkin-Lehner-theory of new forms
- L-series: Mellin transform, functional equation, Euler product decomposition of the L-series of a Hecke-eigenform

Module grade calculation
Grade of the oral exam

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classe and examination
Self studies: 150 hours
- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research on the course content
- preparation for the module examination

Recommendation
The basic notions of algebra and number theory should be well-understood, and also basic principles of complex analysis.
Module: Monotonicity Methods in Analysis [M-MATH-102887]

Responsible: PD Dr. Gerd Herzog
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
          Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

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Mandatory
T-MATH-105877 Monotonicity Methods in Analysis 3 CR Herzog

Competence Certificate
The module will be completed by an oral exam (about 20 min).

Prerequisites
None

Competence Goal
At the end of the course, students can

- name, discuss and apply basic techniques of the order-theoretical methods of analysis,
- apply specific order theory techniques to fixed point problems and differential equations.

Content
- Fixed point theorems in ordered sets and ordered metric spaces.
- Ordered Banach spaces.
- Quasimonotone increasing functions.
- Differential equations and differential inequalities in ordered Banach spaces.

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 90 hours
Attendance: 30 hours
- lectures, problem classes, and examination
Self-studies: 60 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The course “Functional Analysis” is recommended.
Module: Multigrid and Domain Decomposition Methods [M-MATH-102898]

**Responsible:** Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-105863 | Multigrid and Domain Decomposition Methods | 4 CR | Wieners |

**Prerequisites**

None

**Competence Goal**
The students became acquainted with multigrid and domain decomposition methods. They learn algorithms, results on convergence, and representative applications.

**Content**

- The two-grid method
- Classical multigrid theory
- Additive subspace correction method
- Multiplicative subspace correction method
- Multigrid methods for saddle point problems
Module: Neural Networks [M-INFO-100846]

Responsible: Prof. Dr. Alexander Waibel
Organisation: KIT Department of Informatics
Part of: Computer Science

Credits 6
Grading scale Grade to a tenth
Recurrence Each summer term
Duration 1 term
Language German/English
Level 4
Version 1

Mandatory
T-INFO-101383 Neural Networks 6 CR Waibel
# Module: Nonlinear Analysis [M-MATH-103539]

**Responsible:** Prof. Dr. Tobias Lamm  
**Organisation:** KIT Department of Mathematics

**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)

| Credits | 8 | Grading scale | Grade to a tenth | Recurrence | Irregular | Duration | 1 term | Level | 4 | Version | 1 |

**Mandatory**  
| T-MATH-107065 | Nonlinear Analysis | 8 CR | Lamm |

**Prerequisites**  
None
Module: Nonlinear Control Systems [M-ETIT-100371]

Responsible: Prof. Dr.-Ing. Sören Hohmann

Organisation: KIT Department of Electrical Engineering and Information Technology

Part of: Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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Prerequisites

none
# 2.137 Module: Nonlinear Evolution Equations [M-MATH-102877]

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<tr>
<td>T-MATH-105848</td>
<td>8 CR</td>
<td>Nonlinear Evolution Equations</td>
<td>Frey, Schnaubelt</td>
</tr>
</tbody>
</table>

**Competence Certificate**
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**
None

**Competence Goal**
Students can explain the well-posedness theory of semilinear evolution equations in the locally Lipschitz case and apply it to cubic wave equations in 3D. They can also examine these for global existence and blow-up. Based on the fundamentals of interpolation theory for generators, they can also deal with more general nonlinearities in the parabolic case. In this case, they can determine the long-term behaviour with the help of Lyapunov functions and the principle of linearized stability, and apply these results to reaction-diffusion systems. They can derive basic Strichartz inequalities. They can use them to treat the well-posedness and long-term behavior of the nonlinear Schrödinger and wave equations. They master the important proof techniques in the theory of semilinear evolution equations and can at least sketch more complex proofs.

**Content**
- semilinear evolution equations
- wellposedness, global existence versus blow-up
- interpolation theory for generators
- Lyapunov functions, linearized stability
- reaction diffusion systems
- semilinear wave and Schrödinger equations
- Strichartz inequalities

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
Total workload: 240 hours

**Attendance:** 90 h
- lectures, problem classes and examination

**Self studies:** 150 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**
The contents of the modules Functional Analysis and Evolution Equations are strongly recommended. However, the relevant parts of Evolution Equations will be briefly recalled.
2.138 Module: Nonlinear Functional Analysis [M-MATH-102886]

**Responsible:** PD Dr. Gerd Herzog  
**Organisation:** KIT Department of Mathematics

**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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**Mandatory**

| T-MATH-105876 | Nonlinear Functional Analysis | 3 CR | Herzog |

**Competence Certificate**
The module will be completed by an oral exam (about 20 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students can

- name, discuss and apply basic techniques of nonlinear functional analysis,  
- explain the construction of the Brouwer- and Schauder-degree,  
- apply specific techniques of degree theory to nonlinear problems.

**Content**

- The Brouwer degree and its applications  
- The Leray-Schauder degree and its applications  
- Odd mappings  
- Measures of non-compactness and their applications

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 90 hours  
Attendence: 30 hours  
- lectures, problem classes, and examination

Self-studies: 60 hours  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination
Module: Nonlinear Maxwell Equations [M-MATH-105066]

Responsible: Prof. Dr. Roland Schnaubelt
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
          Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)
          Additional Examinations

Mandatory
T-MATH-110283 Nonlinear Maxwell Equations 8 CR Schnaubelt

Competence Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
none

Competence Goal
Students can explain some basic types of nonlinear Maxwell equations and the physical significance of the variables that occur. They are able to prove and discuss local wellposedness theorems in the whole space using energy methods. They can derive Strichartz inequalities for linear Maxwell equations. With their help, they can show improved wellposedness results.

Content
- Maxwell equations with nonlinear material laws
- local wellposedness theory in the whole space using linearisation, apriori estimates and regularisation
- Strichartz inequalities and improved wellposedness theory

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 240 hours
Attendance: 90 h
  - lectures, problem classes and examination
Self studies: 150 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination

Recommendation
The contents of the module "Functional Analysis" are strongly recommended.
Module: Nonlinear Wave Equations [M-MATH-105326]

Responsibles: Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt

Organisation: KIT Department of Mathematics

Part of: Applied Mathematics (Analysis)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

<table>
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Mandatory

T-MATH-110806 Nonlinear Wave Equations 4 CR Reichel, Schnaubelt

Competence Certificate
The module will be completed by an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
Graduates will be able to

- name important properties of nonlinear wave equations,
- describe essential difficulties in the analysis of the initial value problem,
- analyze the short- and long-term behavior of solutions of semilinear wave equations using modern techniques.

Content
The aim of the course is an introduction to methods for analyzing nonlinear wave equations. The aim is to get to know the basics of various important techniques and to apply them to simple models. The following topics will be covered:

- Symmetries and conservation laws
- Fourier transformation, Sobolev spaces
- Energy estimates
- Strichartz estimates
- Local and global well-posedness results
- Vector field methods
- Longtime behavior

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 120 hours

Attendance: 45 h
- lectures, problem classes and examination

Self studies: 75 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The contents of the module "Functional Analysis" are strongly recommended.
2.141 Module: Nonparametric Statistics [M-MATH-102910]

Responsible: PD Dr. Bernhard Klar
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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<th>4 CR</th>
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Competence Certificate
The module will be completed with an oral exam (ca. 20 min).

Prerequisites
None

Competence Goal
By the end of the course, students will be able to

- explain nonparametric statistical tests based on location problems and distinguish them from parametric methods,
- name and explain nonparametric estimation methods for nonparametric regression and density estimation,
- know and apply optimality criteria for the statistical methods covered.

Content

- Introduction to nonparametric models
- Nonparametric tests, especially rank statistics
- Nonparametric density and regression estimation
- Dependence measures or optimal convergence rates

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 120 hours
Attendance: 45 h

- lectures, problem classes and examination
Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The contents of the module 'Probability Theory' are strongly recommended. The module 'Mathematical Statistics' is recommended.
## 2.142 Module: Numerical Analysis of Helmholtz Problems [M-MATH-105764]

<table>
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<tr>
<th>Responsible:</th>
<th>TT-Prof. Dr. Barbara Verfürth</th>
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### Mandatory

| T-MATH-111514 | Numerical Analysis of Helmholtz Problems | 3 CR | Verfürth |

### Competence Certificate

oral examination of circa 30 minutes

### Prerequisites

none

### Module grade calculation

The module grade is the grade of the final oral exam.
Module: Numerical Analysis of Neural Networks [M-MATH-106695]

Responsible: TT-Prof. Dr. Roland Maier
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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Competence Certificate
The module will be completed by an oral exam (about 30 min).

Prerequisites
none

Competence Goal
The goal of the lecture is to provide a mathematical foundation of neural networks from the perspective of numerical analysis. Students know basic definitions and terminology as well as classical approximation results for neural networks. They are familiar with numerical methods for the efficient training of neural networks and can analyze them. Moreover, students can apply the concepts to popular applications in the context of partial differential equations (such as physics-informed neural networks).

Content
- Neural networks
- Approximation results
- Connections to finite element methods
- Numerical methods for the efficient learning
- Physics-informed neural networks

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 h
  - lectures, problem classes and examination
Self studies: 120 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination

Recommendation
A solid background in numerical mathematics is strongly recommended. Basic knowledge of functional analysis and finite element methods is helpful, but not required.
2.144 Module: Numerical Complex Analysis [M-MATH-106063]

Responsible: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 6
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Language German
Level 4
Version 1

Mandatory

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<td>Hochbruck</td>
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Competence Certificate
oral exam of ca. 20 minutes

Prerequisites
none

Module grade calculation
The module grade is the grade of the oral exam.

Workload
total workload: 180 h

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024

**Responsible:** Prof. Dr. Hartwig Anzt

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Prerequisites**

None
Module: Numerical Linear Algebra in Image Processing [M-MATH-104058]

**Responsible:** PD Dr. Volker Grimm

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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</table>

**Mandatory**

| MATH-108402 | Numerical Linear Algebra in Image Processing | 6 CR | Grimm |

**Competence Certificate**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
Graduates can name essential concepts of image processing using numerical linear algebra methods and implement them efficiently.

**Content**
- Linear models of optical devices
- Point spread function and discrete convolution
- Structured matrices and fast transformations
- Large, ill-conditioned linear systems of equations
- Krylov subspace methods, preconditioning
- Several applications

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 180 hours
Attendance: 60 hours
- lectures, problem classes, and examination

Self-studies: 120 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination
Module: Numerical Methods for Differential Equations [M-MATH-102888]

2.147 Module: Numerical Methods for Differential Equations [M-MATH-102888]

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:**  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
Additional Examinations

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<td>Numerical Methods for Differential Equations</td>
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**Competence Certificate**
The module will be completed by a written exam (120 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students

- know important examples of numerical methods for ordinary differential equations as well as the underlying construction principles
- are able to analyze the properties of these methods (in particular their stability, convergence and complexity)
- are able to analyze basic numerical methods for linear partial differential equations
- can explain concepts of modelling with differential equations

**Content**

- Numerical methods for initial value problems (Runge-Kutta methods, multistep methods, order, stability, stiff problems)
- Numerical methods for boundary value problems (finite difference methods for second-order elliptic equations)
- Numerical methods for initial boundary value problems (finite difference methods for parabolic equations and hyperbolic equations)

**Module grade calculation**
The module grade is the grade of the written exam.

**Workload**
Total workload: 240 hours

- Attendance: 90 hours
  - lectures, problem classes, and examination
- Self-studies: 150 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**
It is highly recommended that participants have completed the modules "Numerische Mathematik 1 und 2" as well as "Programmieren: Einstieg in die Informatik und algorithmische Mathematik".

**Responsible:** Prof. Dr. Willy Dörfler  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Prerequisites**  
none

**Competence Goal**

.
2.149 Module: Numerical Methods for Integral Equations [M-MATH-102930]

Responsible: PD Dr. Tilo Arens
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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Competence Certificate
The module examination is carried out by one oral examination (approx. 30 minutes).
By successfully participating in the problem classes by correctly completing 60% of the programming exercise assignments, students will obtain a bonus to the grade of the oral examination. This bonus amounts to an improvement of the grade to the next marking step (a decrease by 0.3 or 0.4, respectively), if the original grade is between 4.0 and 1.3.

Prerequisites
None

Competence Goal
Students are able to name and describe basic methods for numerically solving linear integral equations of the second kind, such as degenerate kernel approximation, the Nyström method, collocation method and Galerkin method, as well as their underlying principles such as interpolation and numerical integration. They are able to apply these methods for numerically solving integral equations and to implement concrete examples on a computer. Students are able to state convergence results concerning these methods and have mastered the application of methods of proof for such results. They can independently derive corresponding results for simple variations of these methods and perform the analysis of the convergence behavior for specific applications.

Content
- Boundary integral operators
- Interpolation
- Quadrature formulae
- Approximation by degenerate kernel functions
- Nyström methods
- Projection methods

Module grade calculation
The grade of the module is the grade of the oral examination, modified by the bonus from the problem class assignments.

Workload
Total workload: 240 hours
Attendance: 90 h
- lectures, problem classes and examination
Self studies: 150 h
- increased understanding of module content by wrapping up lectures at home
- work on exercises
- increased understanding of module content by self study of literature and internet research
- preparing for the examination

Recommendation
Numerical Analysis I
Integral Equations
### M 2.150 Module: Numerical Methods for Maxwell's Equations [M-MATH-102931]

**Responsible:** Prof. Dr. Marlis Hochbruck  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**

| T-MATH-105920 | Numerical Methods for Maxwell's Equations | 6 CR | Hochbruck, Jahnke |
Module: Numerical Methods for Oscillatory Differential Equations [M-MATH-106682]

2.151

**Responsible:** Prof. Dr. Tobias Jahnke  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**

| T-MATH-113437 | Numerical Methods for Oscillatory Differential Equations | 8 CR | Jahnke |

**Competence Certificate**
The module will be completed by an oral exam (about 30 min).

**Prerequisites**
none

**Competence Goal**
The central topic of the lecture are numerical time-integrators for highly oscillatory ordinary and partial differential equations.

After participation, students

- know selected classes of ordinary and partial differential equations with oscillatory solutions and can explain the reason for the oscillators.
- can explain why time-integration of such problems with traditional methods is usually inefficient.
- know different techniques which can be used to construct more efficient methods for selected problems.
- can explain error bounds for such integrators and know the ideas, techniques and assumptions used in the error analysis.

**Content**

- Oscillatory ordinary and partial differential equations: examples and applications
- Construction of time integrators
- Oscillations and resonances
- Error analysis
- Space discretization by Fourier collocation methods

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Annotation**
The module will be offered about every second summer semester.

**Workload**
Total workload: 240 hours

- Attendance: 90 h
  - lectures, problem classes and examination

- Self studies: 150 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination
**Recommendation**
Participants are expected to be familiar with numerical methods for ordinary differential equations (e.g. Runge-Kutta methods) and with concepts required for their analysis (stability, order, local and global error, etc.).
**2.152 Module: Numerical Methods for Time-Dependent Partial Differential Equations [M-MATH-102928]**

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<th>Hochbruck, Jahnke</th>
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Module: Numerical Methods in Computational Electrodynamics [M-MATH-102894]

**Responsible:** Prof. Dr. Willy Dörfler

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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<td>Numerical Methods in Computational Electrodynamics</td>
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**Prerequisites**

none
Module: Numerical Methods in Fluid Mechanics [M-MATH-102932]

**M 2.154 Module: Numerical Methods in Fluid Mechanics [M-MATH-102932]**

**Responsible:** Prof. Dr. Willy Dörfler
PD Dr. Gudrun Thäter

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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<td>T-MATH-105902</td>
<td>Numerical Methods in Fluid Mechanics</td>
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**Competence Certificate**

Oral exam of about 20 minutes.

**Prerequisites**

None

**Competence Goal**

Participants know about the modelling and physical basics that lead to the model equations. They know how to discretize fluidmechanical problems with the finite element method and know especially how to treat the incompressibility condition. They are able to analyze stability and convergence of the presented methods.

**Content**

- Modelling and derivation of the Navier-Stokes equations
- Mathematical and physical representation of energy and stress
- Lax-Milgram theorem, Céa lemma and saddle point theory
- Analytical and numerical treatment of the potential and Stokes flow
- Stability and convergence of the discrete models
- Numerical treatment of the stationary nonlinear equation
- Numerical treatment of the instationary problems
- Applications

**Module grade calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 120 hours

Attendance: 45 h

- lectures, problem classes and examination.

Self studies: 75 h

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination.

**Recommendation**

Basic knowledge in the numerical treatment of differential equations, such as boundary value problems or initial value problems is strongly recommended. Knowledge in functional analysis is recommended.
Module: Numerical Methods in Mathematical Finance [M-MATH-102901]

Responsible: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: 
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

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Mandatory

| T-MATH-105865 | Numerical Methods in Mathematical Finance | 8 CR | Jahnke |

Competence Certificate
oral exam of ca. 30 minutes

Prerequisites
none

Competence Goal
The lecture concentrates on option pricing with numerical methods.

After participation, students

- know how to model the price dynamics of different types of options by stochastic or partial differential equations, and to evaluate the differences between these models.
- know, in particular, the assumptions on which these models are based, which enables them to discuss and question the meaningfulness and reliability of the models.
- know different methods for solving stochastic and partial differential equations numerically, and for solving high-dimensional integration problems.
- are able to implement and apply these methods to different types of options, and to analyze their stability and convergence.

Content

- Options, arbitrage and other basic concepts,
- Black-Scholes equation und Black-Scholes formulas,
- Numerical methods for stochastic differential equations,
- (Multilevel) Monte Carlo methods,
- (Quasi-)Monte Carlo integration,
- Numerical methods for Black-Scholes equations,
- Numerical methods for American options

Module grade calculation
The grade of the module is the grade of the oral exam.

Annotation
The module is offered every second winter term.

Workload
Total workload: 240 hours

Attendance: 90 h
- lectures, problem classes and examination

Self studies: 150 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination
Recommendation
Familiarity with stochastic differential equations, the Ito integral, and the Ito formula is strongly recommended. MATLAB skills are strongly recommended for the programming exercises.
2.156 Module: Numerical Optimisation Methods [M-MATH-102892]

**Responsible:** Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Credits:** 8

**Grading scale:** Grade to a tenth

**Recurrence:** Irregular

**Duration:** 1 term

**Level:** 4

**Version:** 1

**Mandatory**

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<td>Numerical Optimisation Methods</td>
<td>8 CR</td>
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Dörfler, Hochbruck, Jahnke, Rieder, Wieners
2.157 Module: Numerical Simulation in Molecular Dynamics [M-MATH-105327]

Responsible: PD Dr. Volker Grimm
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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Competence Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
None

Competence Goal
Graduates know the basic concepts for implementing numerical simulations in molecular dynamics on serial and parallel computer architectures. They can name the numerical results and procedures required for simulation in molecular dynamics, apply them to specific problems and implement them.

Content
- Linked-cell method for short-range potentials
- Parallel programming with MPI
- Various potentials and molecules
- Time integration methods
- Aspects of numerical geometric integration
- Methods for the simulation of long-range potentials

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classes, and examination
Self-study: 150 hours
- follow-up and deepening of course content,
- work on problem sheets,
- literature study and internet research relating to the course content
- preparation for the module examination

Recommendation
The module M-MATH-102888 (Numerical Methods for Differential Equations) and some programming skills in C (or C++) are recommended.
2.158 Module: Optical Waveguides and Fibers [M-ETIT-100506]

**Responsible:** Prof. Dr.-Ing. Christian Koos

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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**Mandatory**

| T-ETIT-101945 | Optical Waveguides and Fibers | 4 CR | Koos |

**Competence Certificate**

Type of Examination: Oral exam

Duration of Examination: approx. 20 minutes

Modality of Exam: The written exam is offered continuously upon individual appointment.

**Prerequisites**

None

**Competence Goal**

The students

- conceive the basic principles of light-matter-interaction and wave propagation in dielectric media and can explain the origin and the implications of the Lorentz model and of Kramers-Kronig relation,
- are able to quantitatively analyze the dispersive properties of optical media using Sellmeier relations and scientific databases,
- can explain and mathematically describe the working principle of an optical slab waveguide and the formation of guided modes,
- are able to program a mode solver for a slab waveguide in Matlab,
- are familiar with the basic principle of surface plasmon polariton propagation,
- know basic structures of planar integrated waveguides and are able to model special cases with semi-analytical approximations such as the Marcatili method or the effective-index method,
- are familiar with the basic concepts of numerical mode solvers and the associated limitations,
- are familiar with state-of-the-art waveguide technologies in integrated optics and the associated fabrication methods,
- know basic concepts of step-index fibers, graded-index fibers and microstructured fibers,
- are able to derive and solve basic relations for step-index fibers from Maxwell's equations,
- are familiar with the concept of hybrid and linearly polarized fiber modes,
- can mathematically describe signal propagation in single-mode fibers design dispersion-compensated transmission links,
- conceive the physical origin of fiber attenuation effects,
- are familiar with state-of-the-art fiber technologies and the associated fabrication methods,
- can derive models for dielectric waveguide structures using the mode expansion method,
- conceive the principles of directional couplers, multi-mode interference couplers, and waveguide gratings,
- can mathematically describe active waveguides and waveguide bends.
Content

1. Introduction: Optical communications
2. Fundamentals of wave propagation in optics: Maxwell’s equations in optical media, wave equation and plane waves, material dispersion, Kramers-Kroig relation and Sellmeier equations, Lorentz and Drude model of refractive index, signal propagation in dispersive media.
3. Slab waveguides: Reflection from a plane dielectric boundary, slab waveguide eigenmodes, radiation modes, inter- and intramodal dispersion, metal-dielectric structures and surface plasmon polariton propagation.
4. Planar integrated waveguides: Basic structures of integrated optical waveguides, guided modes of rectangular waveguides (Marcatili method and effective-index method), basics of numerical methods for mode calculations (finite difference- and finite-element methods), waveguide technologies in integrated optics and associated fabrication methods.
5. Optical fibers: Optical fiber basics, step-index fibers (hybrid modes and LP-modes), graded-index fibers (infinitely extended parabolic profile), microstructured fibers and photonic-crystal fibers, fiber technologies and fabrication methods, signal propagation in single-mode fibers, fiber attenuation, dispersion and dispersion compensation.
6. Waveguide-based devices: Modeling of dielectric waveguide structures using mode expansion and orthogonality relations, multimode interference couplers and directional couplers, waveguide gratings, material gain and absorption in optical waveguides, bent waveguides.

Module grade calculation
The module grade is the grade of the oral exam.
There is, however, a bonus system based on the problem sets that are solved during the tutorials: During the term, 3 problem sets will be collected in the tutorial and graded without prior announcement. If for each of these sets more than 70% of the problems have been solved correctly, a bonus of 0.3 grades will be granted on the final mark of the oral exam.

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies.

Recommendation
Solid mathematical and physical background, basic knowledge of electrodynamics

Literature
B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics
G.P. Agrawal: Fiber-optic communication systems
C.-L. Chen: Foundations for guided-wave optics
Katsunari Okamoto: Fundamentals of Optical Waveguides
K. Iizuka: Elements of Photonics
Module: Optimal Control and Estimation [M-ETIT-102310]

**Responsible:** Prof. Dr.-Ing. Sören Hohmann

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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<td>Optimal Control and Estimation</td>
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**Prerequisites**

none
### 2.160 Module: Optimisation and Optimal Control for Differential Equations  
[M-MATH-102899]

<table>
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<tr>
<th>Responsible</th>
<th>Prof. Dr. Christian Wieners</th>
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|                   | Mathematical Specialization (Elective Field Mathematical Specialization) |
| Additional Examinations |                               |

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**Prerequisites**
none
2.161 Module: Optimization in Banach Spaces [M-MATH-102924]

**Responsible:** Prof. Dr. Roland Griesmaier

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Mandatory**

| T-MATH-105893 | Optimization in Banach Spaces | 5 CR | Griesmaier, Hettlich |

**Competence Certificate**
The module will be completed by an oral exam (approx. 30 min).

**Prerequisites**
none

**Competence Goal**
The students can transfer properties from finite dimensional optimization problems to infinite dimensional cases. Furthermore, they can apply these results to problems from approximation theory, calculus of variation and optimal control. The students know about the main theorems and their proofs and can explain conclusions with the help of examples.

**Content**
Basics from Functional Analysis (in particular separation theorems, properties of convex functions and generalized derivatives), duality theory of convex problems, differentiable optimization problems (Lagrange multiplier), sufficient optimality conditions, existence results, applications in approximation theory, calculus of variation, and optimal control theory.

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 150 hours
Attendance: 60 hours
- lecture including course related examinations
Self-studies: 90 hours
- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research relating to the course content
- preparation for the module examination

**Recommendation**
Some basic knowledge of finite dimensional optimization theory and functional analysis is desirable.
Module: Optimization of Dynamic Systems [M-ETIT-100531]

Responsible: Prof. Dr.-Ing. Sören Hohmann
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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Competence Certificate
The assessment consists of a written exam (120 min) taking place in the recess period.

Prerequisites
none

Competence Goal
- The students know as well the mathematical basics as the fundamental methods and algorithms to solve constraint and unconstraint nonlinear static optimization problems.
- They can solve constraint and unconstraint dynamic optimization by using the calculus of variations approach and the Dynamic Programming method.
- Also they are able to transfer dynamic optimization problem to static problems.
- The students know the mathematic relations, the pros and cons and the limits of the particular optimization methods.
- They can transfer problems from other fields of their studies in a convenient optimization problem formulation and they are able to select and implement suitable optimization algorithms for them by using common software tools.

Content
The module teaches the mathematical basics that are required to solve optimization problems. The first part of the lecture treats methods for solving static optimization problems. The second part of the lecture focuses on solving dynamic optimization problems by using the method of Euler-Lagrange and the Hamilton method as well as the dynamic programming approach.

Module grade calculation
The module grade is the grade of the written exam.

Workload
Each credit point stands for an amount of work of 30h of the student. The amount of work includes
1. presence in lecture/exercises/tutorial(optional) (2+1 SWS: 45h1.5 LP)
2. preparation/postprocessing of lecture/exercises (90h3 LP)
3. preparation/presence in the written exam (15h0.5 LP)
Module: Parallel Computing [M-MATH-101338]

2.163 Module: Parallel Computing [M-MATH-101338]

**Responsible:** PD Dr. Mathias Krause
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Mandatory**

| T-MATH-102271 | Parallel Computing | 5 CR | Krause, Wieners |

**Prerequisites**

None
Module: Particle Physics I [M-PHYS-102114]

**Responsible:** Prof. Dr. Torben Ferber  
Prof. Dr. Ulrich Husemann  
Prof. Dr. Markus Klute  
Prof. Dr. Günter Quast  
PDr. Klaus Rabbertz

**Organisation:** KIT Department of Physics  
Part of: Experimental Physics (Experimental Physics)

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**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Competence Goal**

Students can classify elementary particles and qualitatively analyze interactions between elementary particles using symmetries, Feynman diagrams and Lagrangian densities. Combining this knowledge with knowledge of elementary particle detection, students will be able to discuss the operation of modern particle physics detectors. Students will be able to interpret current data and figures from the scientific literature on particle physics and present the current state of research and important "open questions". Students will be able to apply techniques of statistical data analysis and Monte Carlo simulation to simple particle physics problems and perform basic characterization of silicon track detectors in the laboratory.

**Content**

*Lecture:*

- Basic concepts of particle physics
- Detectors and accelerators
- Basics of the Standard Model
- Tests of the electroweak theory
- Flavour physics
- QCD
- Physics at high transverse momenta
- Higgs physics
- Physics of massive neutrinos
- Physics beyond the Standard Model

*Practical exercises:*

- Current methods of Monte Carlo simulation and data analysis in particle physics.
- Measurements on modern silicon track detectors.

**Annotation**

For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation numbers and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

**Workload**

approx. 240 hours consisting of attendance time (60 hours), follow-up of the lecture incl. exam preparation and preparation of the exercises (180 hours)
Recommendation
Basic knowledge of experimental particle physics from the lecture Modern Experimental Physics III in the bachelor's program in physics.

Literature

Additional references will be given in lecture.
# 2.165 Module: Pattern Recognition [M-INFO-100825]

**Responsible:** Prof. Dr.-Ing. Jürgen Beyerer  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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Module: Percolation [M-MATH-102905]

Responsible: Prof. Dr. Günter Last
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

Credits: 5
Grading scale: Grade to a tenth
Recurrence: Irregular
Duration: 1 term
Level: 4
Version: 2

M Mandatory
T-MATH-105869 Percolation

Competence Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
none

Competence Goal
The students
- are acquainted with basic models of discrete and continuum percolation,
- acquire the skills needed to use specific probabilistic and graph-theoretical methods for the analysis of these models,
- know how to work self-organised and self-reflexive.

Content
- Bond and site percolation on graphs
- Infinite clusters and critical probabilities
- Asymptotics of cluster sizes
- Uniqueness of the infinite cluster
- Continuous percolation

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 150 hours
Attendance: 60 hours
- lectures, problem classes, and examination
Self-studies: 90 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The contents of the module Probability Theory are recommended.
### 2.167 Module: Physical Foundations of Cryogenics [M-CIWVT-103068]

**Responsible:** Prof. Dr.-Ing. Steffen Grohmann  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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</table>

**Competence Certificate**

Learning control is an oral examination lasting approx. 30 minutes.

**Prerequisites**

None

**Competence Goal**

Understanding of the mechanisms of entropy generation, and the interaction of the first and the second law in thermodynamic cycles; understanding of cryogenic material properties; application, analysis and assessment of real gas models for classical helium I; understanding of quantum fluid properties of helium II based on Bose-Einstein condensation, understanding of cooling principles at lowest temperatures.

**Content**

Relation between energy and temperature, energy transformation on microscopic and on macroscopic scales, physical definitions of entropy and temperature, thermodynamic equilibria, reversibility of thermodynamic cycles, helium as classical and as quantum fluid, low-temperature material properties, cooling methods at temperatures below 1 K.

**Module grade calculation**

The grade of the oral examination is the module grade.

**Workload**

- Attendance time (Lecture): 45 h
- Homework: 45 h
- Exam Preparation: 90 h

**Literature**

**Module: Poisson Processes [M-MATH-102922]**

**Responsible:** Prof. Dr. Günter Last  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Credits:** 5  
**Grading scale:** Grade to a tenth  
**Recurrence:** Irregular  
**Duration:** 1 term  
**Level:** 4  
**Version:** 1

### Mandatory

| T-MATH-105922 Poisson Processes | 5 CR | Fasen-Hartmann, Hug, Last, Nestmann, Winter |

**Competence Certificate**  
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**  
none

**Competence Goal**  
The students know about important properties of the Poisson process. The focus is on probabilistic methods and results which are independent of the specific phase space. The students understand the central role of the Poisson process as a specific point process and as a random measure.

**Content**

- The Poisson process as particular point process
- Multivariate Mecke equation
- Superpositions, markings and thinnings
- Characterizations of the Poisson process
- Stationary Poisson and point processes
- Balanced allocations and the Gale-Shapley algorithm
- Compound Poisson processes
- Wiener-Ito integrals
- Fock space representation

**Module grade calculation**  
The module grade is the grade of the oral exam.

**Workload**

Total workload: 150 hours  
Attendance: 60 hours

- lectures, problem classes, and examination

Self-studies: 90 hours

- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination

**Recommendation**  
The contents of the module Probability Theory are recommended.
Module: Potential Theory [M-MATH-102879]

**Responsible:** Prof. Dr. Roland Griesmaier  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Competence Certificate**  
The module will be completed by an oral exam (30 min).

**Prerequisites**  
None

**Competence Goal**  
Students can explain basic properties of harmonic functions and prove existence and uniqueness of solutions to boundary value problems for the Laplace equation in interior and exterior domains using integral equation techniques. They master representation theorems and are able to apply single- and double layer potentials to solve boundary value problems.

**Content**

- Properties of harmonic functions  
- Existence and uniqueness of boundary value problems for the Laplace equation  
- Fundamental solutions and Green's functions  
- Single- and double layer potentials  
- Integral equations

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

- **Total workload:** 240 hours  
- **Attendance:** 90 hours
  - lectures, problem classes, and examination
- **Self-studies:** 150 hours
  - follow-up and deepening of the course content  
  - work on problem sheets  
  - literature study and internet research relating to the course content  
  - preparation for the module examination

Responsible: Prof. Dr. Daniel Hug
Organisation: KIT Department of Mathematics
Part of:
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

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Competence Certificate
The module will be completed by an oral exam (ca. 30 min).

Prerequisites
none

Competence Goal
The students
- know basic problems of combinatorial optimization as discussed in the lectures and are able to explain them,
- know typical methods for the probabilistic analysis of algorithms and combinatorial optimization problems and are able to use them for the solution of specific optimization problems,
- are familiar with the essential techniques of proof and are able to explain them,
- know how to work in a self-organized and self-reflexive manner.

Content
This course is devoted to the analysis of algorithms and combinatorial optimization problems in a probabilistic framework. A natural setting for the investigation of such problems is often provided by a (geometric) graph. For a given system (graph), the average or most likely behavior of an objective function of the system will be studied. In addition to asymptotic results, which describe a system as its size increases, quantitative laws for systems of fixed size will be described. Among the specific problems to be explored are
- the long-common-subsequence problem,
- packing problems,
- the Euclidean traveling salesperson problem,
- minimal Euclidean matching,
- minimal Euclidean spanning tree.

For the analysis of problems of this type, several techniques and concepts have been developed and will be introduced and applied in this course. Some of these are
- concentration inequalities and concentration of measure,
- subadditivity and superadditivity,
- martingale methods,
- isoperimetry,
- entropy.

Module grade calculation
The module grade is the grade of the oral exam.
Workload
Total workload: 240 hours
Attendance: 90 hours
  • lectures, problem classes, and examination
Self-studies: 150 hours
  • follow-up and deepening of the course content
  • work on problem sheets
  • literature study and internet research related to the course content
  • preparation for the module exam.

Recommendation
It is recommended to have taken the module 'Probability Theory' from the Bachelor program beforehand.
2.171 Module: Process Modeling in Downstream Processing [M-CIWVT-103066]

**Responsible:** apl. Prof. Dr. Matthias Franzreb

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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**Competence Certificate**
The examination is an oral examination with a duration of about 20 minutes (section 4 subsection 2 number 2 SPO). The grade of the oral examination is the module grade.

**Prerequisites**
None

**Competence Goal**
Students are able to sum up and explain equilibrium and kinetic equations relevant for chromatography modeling. They are able to explain the methods used for determination of equilibrium and kinetic parameters and can discuss examples. They are familiar with the principle of complex downstream processes, e.g. simulated moving beds, and can explain the differences to conventional chromatography. Using commercial software they are able to simulate chromatography processes and to analyze the results. On this basis they can optimize process parameters and fit them in order to meet given targets such as purity or yield. They can evaluate different processes and choose the variant for a given task.

**Content**
Fundamentals and practical examples of chromatography modeling,
Design rules for Simulated Moving Beds, Design of Experiments (DOE)

**Workload**
- Attendance time (Lecture): 30 h
- Homework: 60 h
- Exam Preparation: 30 h
2.172 Module: Processing of Nanostructured Particles [M-CIWVT-103073]

Responsible: Prof. Dr.-Ing. Hermann Nirschl
Organisation: KIT Department of Chemical and Process Engineering
Part of: Chemical and Process Engineering (Chemical and Process Engineering)

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<td>Each winter term</td>
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Mandatory
T-CIWVT-106107 Processing of Nanostructured Particles 6 CR Nirschl

Competence Certificate
Learning control is an oral examination lasting approx. 25 minutes.

Prerequisites
None

Competence Goal
Ability to design a process technology for the manufacturing and production of nanoscale particles

Content
Development of technical process in particle engineering; particle characterisation, interface engineering, particle synthesis; typical processes: grinding, mixing, granulation, selective separation, classifying; fundamentals of apparatus and devices; simulation techniques, simulation tools

Module grade calculation
The grade of the oral examination is the module grade.

Workload
- Attendance time (Lecture): 60 h
- Homework: 60 h
- Exam Preparation: 60 h

Literature
Skriptum zur Vorlesung
# 2.173 Module: Random Graphs and Networks [M-MATH-106052]

**Responsible:** Prof. Dr. Daniel Hug  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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</table>

**Mandatory**

| T-MATH-112241 | Random Graphs and Networks | 8 CR | Hug |

**Competence Certificate**  
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**  
none

**Competence Goal**  
Students

- know the basic models of random graphs and their properties,
- are familiar with probabilistic techniques for the investigation of random graphs,
- are able to work in a self-organized and reflexive manner.

**Content**  
In the course, models of random graphs and networks are presented and methods will be developed which allow to state and prove results about the structure of such models.

In particular, the following models are treated:

- Erdős–Rényi graphs
- Configuration models
- Preferential-Attachment graphs
- Generalized inhomogeneous random graphs
- Geometric random graphs

and the following methods are addressed:

- Branching processes
- Coupling arguments
- Probabilistic bounds
- Martingales
- Local convergence of random graphs

**Module grade calculation**  
The grade of the module is the grade of the oral exam.

**Annotation**  
can not be completed together with M-MATH-102951 - Random Graphs
**Workload**
Total workload: 240 hours

Attendance: 90 hours
  - lectures, problem classes, and examination

Self-studies: 150 hours
  - follow-up and deepening of the course content
  - work on problem sheets
  - literature study and internet research related to the course content
  - preparation for the module exam.

**Recommendation**
The contents of the module 'Probability Theory' are strongly recommended.
Module: Real-Time Systems [M-INFO-100803]

**Responsible:** Prof. Dr.-Ing. Thomas Längle

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

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2.175 Module: Regularity for Elliptic Operators [M-MATH-106696]

Responsible: apl. Prof. Dr. Peer Kunstmann
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
Mathematical Specialization (Elective Field Mathematical Specialization)

Addition Examinations

Credits: 6
Grading scale: Grade to a tenth
Recurrence: Irregular
Duration: 1 term
Language: English
Level: 4
Version: 1

Mandatory

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Kunstmann

Competence Certificate
The module will be completed by an oral exam (about 30 min).

Prerequisites
none

Competence Goal
The students

• can explain methods for definition of elliptic operators,
• can name results on spectral properties in $L^q$ and relate them,
• can explain the relevance of heat kernel estimates and sketch corresponding methods of proof,
• can sketch the construction of the $H^\infty$ functional calculus and name classes of elliptic operators for which it is bounded,
• can explain the concept of $L^p$ maximal regularity and its relation to other parts of the theory and can name examples,
• have mastered the important techniques of proofs for regularity properties of elliptic operators,
• are able to start a master thesis in the field.

Content

• elliptic operators in divergence and non-divergence form
• elliptic operators on domains with boundary conditions
• heat kernel estimates for elliptic operators
• spectrum of elliptic operators in Lebesgue spaces $L^q$
• maximal $L^p$ regularity for the parabolic problem
• $H^\infty$ functional calculus for elliptic operators
• $L^q$ theory for parabolic boundary value problems

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 h
• lectures, problem classes and examination
Self studies: 120 h
• follow-up and deepening of the course content,
• work on problem sheets,
• literature study and internet research on the course content,
• preparation for the module examination

Recommendation
The modules "Functional Analysis" and "Spectral Theory" are strongly recommended.
Module: Riemann Surfaces [M-MATH-106466]

Responsible: Prof. Dr. Frank Herrlich
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

| Credits | 8 |
| Grading scale | Grade to a tenth |
| Recurrence | Irregular |
| Duration | 1 term |
| Language | German |
| Level | 4 |
| Version | 1 |

Mandatory

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Competence Certificate
Oral examination of ca. 30 minutes.

Prerequisites
None

Competence Goal
Students know
- essential structural properties of Riemann surfaces,
- topological, analytic and algebraic methods for the investigation of Riemann surfaces, and are able to apply them.

Content
- Definition of Riemann surfaces
- holomorphic and meromorphic functions on Riemann surfaces
- Compact Riemann surfaces
- The Riemann-Roch theorem
- Uniformization, Fuchsian groups and hyperbolic metric
- Classification of compact Riemann surfaces

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 240 hours
Attendance: 90 h
- lectures, problem classes and examination
Self studies: 150 h
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
Some knowledge of complex analysis (e.g. "Analysis 4") is strongly recommended as well as the modules "Elementary Geometry" and "Introduction to Algebra and Number Theory".
Module: Robotics I - Introduction to Robotics [M-INFO-100893]

**Responsible:** Prof. Dr.-Ing. Tamim Asfour

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

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### Credits

6

### Grading scale

Grade to a tenth

### Recurrence

Each winter term

### Duration

1 term

### Language

German/English

### Level

4

### Version

3

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<th>T-INFO-108014</th>
<th>Robotics I - Introduction to Robotics</th>
<th>6 CR</th>
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### Competence Certificate

See partial achievements (Teilleistung)

### Prerequisites

See partial achievements (Teilleistung)

### Competence Goal

The student is able to apply the presented concepts to simple and realistic tasks from robotics. This includes mastering and deriving the mathematical concepts relevant for robot modeling. Furthermore, the student masters the kinematic and dynamic modeling of robot systems, as well as the modeling and design of simple controllers. The student knows the algorithmic basics of motion and grasp planning and can apply these algorithms to problems in robotics. He/she knows algorithms from the field of image processing and is able to apply them to problems in robotics. He/she is able to model and solve tasks as a symbolic planning problem. The student has knowledge about intuitive programming procedures for robots and knows procedures for programming and learning by demonstration.

### Content

The lecture provides an overview of the fundamentals of robotics using the examples of industrial robots, service robots and autonomous humanoid robots. An insight into all relevant topics is given. This includes methods and algorithms for robot modeling, control and motion planning, image processing and robot programming. First, mathematical basics and methods for kinematic and dynamic robot modeling, trajectory planning and control as well as algorithms for collision-free motion planning and grasp planning are covered. Subsequently, basics of image processing, intuitive robot programming especially by human demonstration and symbolic planning are presented.

In the exercise, the theoretical contents of the lecture are further illustrated with examples. Students deepen their knowledge of the methods and algorithms by independently working on problems and discussing them in the exercise. In particular, students can gain practical programming experience with tools and software libraries commonly used in robotics.

### Workload

Lecture with 3 SWS + 1 SWS Tutorial, 6 LP

6 LP corresponds to 180 hours, including

15 * 3 = 45 hours attendance time (lecture)
15 * 1 = 15 hours attendance time (tutorial)
15 * 6 = 90 hours self-study and exercise sheets
30 hours preparation for the exam
**Module: Robotics II - Humanoid Robotics [M-INFO-102756]**

**Responsible:** Prof. Dr.-Ing. Tamim Asfour

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

**Credits:** 3
**Grading scale:** Grade to a tenth
**Recurrence:** Each summer term
**Duration:** 1 term
**Language:** English
**Level:** 4
**Version:** 3

**Mandatory**

| T-INFO-105723 | Robotics II - Humanoid Robotics | 3 CR | Asfour |

**Competence Certificate**
See partial achievements (Teilleistung)

**Prerequisites**
See partial achievements (Teilleistung)

**Competence Goal**
The students have an overview of current research topics in autonomous learning robot systems using the example of humanoid robotics. They are able to classify and evaluate current developments in the field of cognitive humanoid robotics.
The students know the essential problems of humanoid robotics and are able to develop solutions on the basis of existing research.

**Content**
The lecture presents current work in the field of humanoid robotics that deals with the implementation of complex sensorimotor and cognitive abilities. In the individual topics different methods and algorithms, their advantages and disadvantages, as well as the current state of research are discussed.
The topics addressed are: Applications and real world examples of humanoid robots; biomechanical models of the human body, biologically inspired and data-driven methods of grasping, imitation learning and programming by demonstration; semantic representations of sensorimotor experience as well as cognitive software architectures of humanoid robots.

**Workload**
Lecture with 2 SWS, 3 CP.
3 LP corresponds to approx. 90 hours, thereof:
approx. 15 * 2h = 30 Std. Attendance time
approx. 15 * 2h = 30 Std. Self-study prior/after the lecture
approx. 30 Std. Preparation for the exam and exam itself

**Recommendation**
Having visited the lectures on Robotics I - Introduction to Robotics and Mechano-Informatics and Robotics is recommended.
2.179 Module: Robotics III - Sensors and Perception in Robotics [M-INF-104897]

Responsible: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: Computer Science

Credits: 3
Grading scale: Grade to a tenth
Recurrence: Each summer term
Duration: 1 term
Language: English
Level: 4
Version: 1

Mandatory
T-INFO-109931 Robotics III - Sensors and Perception in Robotics 3 CR Asfour

Competence Certificate
See partial achievements (Teilleistung)

Prerequisites
See partial achievements (Teilleistung)

Competence Goal
Students can name the main sensor principles used in robotics.
Students can explain the data flow from physical measurement through digitization to the use of the recorded data for feature extraction, state estimation and semantic scene understanding.
Students are able to propose and justify suitable sensor concepts for common tasks in robotics.

Content
The lecture supplements the lecture Robotics I with a broad overview of sensors used in robotics. The lecture focuses on visual perception, object recognition, semantic scene interpretation, and (inter-)active perception. The lecture is divided into two parts:

In the first part a comprehensive overview of current sensor technologies is given. A basic distinction is made between sensors for the perception of the environment (exteroceptive) and sensors for the perception of the internal state (proprioceptive).

The second part of the lecture concentrates on the use of exteroceptive sensors in robotics. The topics covered include tactile exploration and visual data processing, including advanced topics such as feature extraction, object localization, semantic scene interpretation, and (inter-)active perception.

Workload
Lecture with 2 SWS, 3 LP
3 LP corresponds to 90 hours, including
15 * 2 = 30 hours attendance time
15 * 2 = 30 hours self-study
30 hours preparation for the exam

Recommendation
Attending the lecture Robotics I – Introduction to Robotics is recommended.
2.180 Module: Ruin Theory [M-MATH-104055]

**Responsible:** Prof. Dr. Vicky Fasen-Hartmann

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

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</table>

**Mandatory**

| T-MATH-108400 | Ruin Theory | 4 CR | Fasen-Hartmann |

**Competence Certificate**
The module will be completed by an oral exam (approx. 20 min).

**Prerequisites**
None

**Competence Goal**
Students are able to
- name and discuss key concepts and results of ruin theory with applications in actuarial mathematics and can apply them to examples,
- apply specific probabilistic methods to analyse risk processes,
- master proof techniques,
- work in a self-orientated and reflective manner.

**Content**
- renewal theory
- classical risk process of Cramér and Lundberg
- asymptotic behaviour of the probability of ruin probability if the Lundberg constant exists (losses with light tailed distributions)
- subexponential distributions
- asymptotic behaviour of the probability of ruin if the losses are subexponentially distributed (losses with heavy tailed distributions)
- approximation of the ruin probability
- integrated risk processes
- portfolio of risk processes

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
Total workload: 120 hours
Attendance: 45 hours
- lectures and problem classes including the examination
Self studies: 75 hours
- follow-up and deepening of the course content
- work on problem sheets
- literature and internet research on the course content
- preparation for the module examination

**Recommendation**
The content of the module "Probability Theory" is recommended.
2.181 Module: Scattering Theory [M-MATH-102884]

Responsible: PD Dr. Frank Hettlich
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits | 8 | Grading scale | Grade to a tenth | Recurrence | Irregular | Duration | 1 term | Level | 4 | Version | 1

Mandatory
T-MATH-105855 Scattering Theory 8 CR Arens, Griesmaier, Hettlich

Competence Certificate
The module will be completed by an oral exam (~30min.)

Prerequisites
none

Competence Goal
The students can prove and apply basic properties of solutions of the Helmholtz equation in the interior and in the exterior of a domain. They know about the representation theorems for such solutions. Students can explain the existence theory of corresponding boundary value problems by integral equations and/or variational formulations including appropriate proofs. Furthermore, the students can show and apply the dependence of a scattered field on the scattering object and the wave number as well as the relationship with its far field pattern.

Content
- Helmholtz equation and elementary soultions
- Greens representation theorems
- Existence and uniqueness of scattering problems
- Radiation condition and far field pattern

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240h
Attendance: 90h
- lecture, problem class, examination
Self-studies: 150h
- follow-up and deepening of the course content
- work on problem sheets
- literature study and internet research related to the course content
- preparation for the module exam

Recommendation
One of the following modules should already be covered: functional analysis or integral equations
2.182 Module: Scattering Theory for Time-dependent Waves [M-MATH-106664]

Responsibility: Prof. Dr. Roland Griesmaier
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Analysis)
          Applied Mathematics (Elective Field Applied Mathematics)
          Mathematical Specialization (Elective Field Mathematical Specialization)
          Additional Examinations

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Mandatory

| T-MATH-113416 | Scattering Theory for Time-dependent Waves | 6 CR | Griesmaier |

Competence Certificate
The module will be completed with an oral exam of about 30 minutes.

Prerequisites
None

Competence Goal
The students can prove and apply basic properties of solutions of the wave equation in interior or exterior domains. They know about representation theorems for such solutions and can apply the Fourier-Laplace-transform to analyze causal solutions. Students master the existence and uniqueness theory of associated boundary value problems using integral equations and retarded single and double layer potentials including proofs. Furthermore, the students can apply these results to scattering problems and explain the dependence of scattered waves on the scattering object as well as the relationship with its far field pattern.

Content
- Wave equations and elementary solutions
- Representation theorems
- Fourier-Laplace-transform
- Boundary element formulations of boundary value problems for the wave equation
- Existence and uniqueness of solutions to interior and exterior boundary value problems
- Scattering problems and far field patterns

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 180 hours
Attendance: 60 h
Self studies: 120 h

Recommendation
The modules Functional Analysis and/or Integral Equations are recommended.
M 2.183 Module: Selected Methods in Fluids and Kinetic Equations [M-MATH-105897]

Responsible: Prof. Dr. Wolfgang Reichel
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 3
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Language English
Level 4
Version 1

Mandatory
T-MATH-111853 Selected Methods in Fluids and Kinetic Equations 3 CR

Competence Certificate
The module will be completed with an oral exam (approx. 30 min).

Prerequisites
none

Competence Goal
The main aim of this lecture is to introduce students to tools and techniques developed in recent years to analyze the evolution of fluids and kinetic equations. The students will learn how to use these techniques and how to apply them to families of equations.

Content
In this lecture we discuss selected techniques and tools that have lead to significant progress in the analysis of fluids and kinetic equations. These, for instance, include:
- energy methods and local well-posedness results (e.g. fixed point results, Osgood lemma)
- Newton iteration
- Cauchy-Kowalewskaya and ghost energy approaches

No prior knowledge of fluids or kinetic equations is required.

Module grade calculation
The grade of the module is the grade of the oral exam.

Workload
Total workload: 90 hours
Attendance: 30 h
- lectures and examination
Self studies: 60 h
- follow-up and deepening of the course content,
- literature study and internet research on the course content,
- preparation for the module examination

Recommendation
The modules "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.
2.184 Module: Selected Topics in Harmonic Analysis [M-MATH-104435]

**Responsible:** Prof. Dr. Dirk Hundertmark  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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**Mandatory**

| T-MATH-109065 | Selected Topics in Harmonic Analysis | 3 CR | Hundertmark |

**Prerequisites**

None

**Competence Goal**

The students are familiar with the concepts of singular integral operators and weighted estimates in Harmonic Analysis. They know the relations between the BMO space and the Muckenhoupt weights and also how to use dyadic analysis operators to obtain estimates for Calderon-Zygmund operators.

**Content**

- Calderon-Zygmund and Singular Integral operators  
- BMO space and Muckenhoupt weights  
- Reverse Holder Inequality and Factorisation of Ap weights  
- Extrapolation Theory and weighted norm inequalities for singular integral operators
2.185 Module: Semigroup Theory for the Navier-Stokes Equations [M-MATH-106663]

**Responsible:** Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Mandatory**

| T-MATH-113415 | Semigroup Theory for the Navier-Stokes Equations | 6 CR | Tolksdorf |

**Competence Certificate**
The module will be completed with an oral exam of about 30 minutes.

**Prerequisites**
None

**Competence Goal**
After a successful participation of the course, students are familiar with essential concepts of semigroup theory, such as analytic semigroups and fractional powers of sectorial operators. They are able to apply these concepts to the Stokes operator and derive basic regularity properties of solutions to the Stokes equations. Furthermore, they can use these concepts to construct solutions to the Navier-Stokes equations in critical spaces through an iteration scheme.

**Content**
Content from abstract semigroup theory:
- Sectorial operators
- Analytic semigroups
- Fractional powers

Content from fluid mechanics:
- Helmholtz decomposition
- Bogovskii operator
- Stokes operator
- Mapping properties of the Stokes semigroup
- Solvability of the Navier-Stokes equations in critical spaces

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 180 hours

**Attendance:**
- 60 h lectures, problem classes and examination

**Self studies:**
- 120 h follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research on the course content,
- preparation for the module examination

**Recommendation**
The following modules are strongly recommended: *Functional Analysis* and *Classical Methods for Partial Differential Equations*.
2.186 Module: Seminar [M-MATH-102730]

Responsible: PD Dr. Stefan Kühnlein
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (mandatory)  
Additional Examinations

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<td>German/English</td>
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Elective Seminar (Election: 1 item)

| T-MATH-105686 | Seminar Mathematics | 3 CR | Kühnlein |

Competence Certificate
The control of success (pass/fail) is based on a seminar talk lasting at least 45 minutes.

Prerequisites
None

Competence Goal
At the end of the module, participants should

- have analyzed a specific problem in a mathematical area
- be able to discuss subject-specific problems in the given context and present as well as defend them, using suitable media
- have summarized the most relevant results of their topic
- have communicative, organizational and didactic skills in complex problem analyses at their disposal. They can use techniques of scientific work.

Content
The specific content is based on the seminar topics being offered.

Module grade calculation
Omitted, as ungraded (pass/fail)

Workload
Total work load: 90 hours
Attendance: 30 hours
Self studies: 60 hours

- Preparation of the scientific content of the talk
- Preparation of a didactical concept for the talk
- Preparation of the presentation (blackboard, beamer, etc.)
- Getting practice for the talk, creating a hand-out
# 2.187 Module: Seminar Advanced Topics in Parallel Programming [M-INFO-101887]

**Responsible:** Prof. Dr. Achim Streit  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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**Mandatory**

| T-INFO-103584 | Seminar Advanced Topics in Parallel Programming | 3 CR | Streit |
2.188 Module: Signal Processing with Nonlinear Fourier Transforms and Koopman Operators [M-ETIT-106675]

**Responsible:** Prof. Dr.-Ing. Sander Wahls

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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<td>Signal Processing with Nonlinear Fourier Transforms and Koopman Operators</td>
<td>6 CR</td>
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**Competence Certificate**
The examination in this module consists of programming assessments and a graded written examination of 120 minutes.

The programming assignments are either pass or fail. They must be passed during the lecture period for admission to the written examination.

**Prerequisites**
none

**Competence Goal**

Students

- understand the basic theory of linear operator on Hilbert spaces and can analyze simple operators analytically
- know the use cases for selected integrable partial differential equations (PDEs) and can apply them under non-ideal circumstances (small non-integrable terms)
- can determine the PDE corresponding to a given Lax-pair and check if the PDE is actually integrable (i.e. check if the Lax pair is “fake”)
- understand the theory of nonlinear Fourier analysis for selected PDEs and can compute nonlinear (inverse) Fourier transforms numerically and, in simple cases, analytically
- know and implement practical engineering applications of nonlinear Fourier transforms
- understand the theory of the Koopman operator including selected engineering applications
- compute Koopman spectra numerically using data-driven methods and use them in practical engineering applications
Content
This module introduces students to signal processing methods that rely on nonlinear Fourier transforms and Koopman operators. These methods allow us to transform large classes of nonlinear systems such that they essentially behave like linear systems. They can also be used to decompose signals driven by such systems into physically meaningful nonlinear wave components (for example, solitons).

While these methods originated in mathematical physics, there has been a growing interesting of exploiting their unique capabilities in engineering contexts. The goal of this module is to give engineering students a practical introduction to this area. It provides the necessary theoretical background, enables students to apply the methods in practice via computer assignments, and discusses recent research from the engineering literature.

The following topics will be discussed:

- Introduction to linear operators on Hilbert spaces
- Integrable model systems (Korteweg-de Vries equation, Nonlinear Schrödinger equation)
- Lax-integrable systems (representations of Lax pairs, fake Lax pairs, conserved quantities)
- Solution of integrable model systems using nonlinear Fourier transforms (inverse scattering method) and the unified transform method
- Physical interpretation of nonlinear Fourier spectra (in particular, solitons)
- Practical applications of nonlinear Fourier transforms
- Theoretical properties of Koopman operators
- Data-driven computation of Koopman operators (residual dynamic mode decomposition)
- Practical applications of Koopman operators

Module grade calculation
The module grade is the grade of the written exam.

Annotation
Some tutorial sessions will be classically devoted to solving pen and paper problems, but in others students will be working on their practical computer assignments. For the latter, students have to bring their own laptops with Matlab installed. The solutions of the computer assignments must be submitted by the provided deadlines, which are typically one week after the corresponding tutorial has taken place.

Workload
The workload includes:

1. attendance in lectures and tutorials: 15*4 h = 60 h
2. preparation / follow-up: 30*3 h = 60 h
3. finishing programming assignments: 30 h
4. preparation of and attendance in examination: 30 h

A total of 180 h = 6 CR

Recommendation
Familiarity with signals and systems at the Bachelor level (Fourier and Laplace transforms, linear systems, etc.) is assumed.
### 2.189 Module: Sobolev Spaces [M-MATH-102926]

**Responsible:** Prof. Dr. Roland Schnaubelt  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Analysis)  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
- Additional Examinations

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**Required Courses**

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<tbody>
<tr>
<td>T-MATH-105896</td>
<td>Sobolev Spaces</td>
<td>8 CR</td>
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</table>

**Competition Certificate**

The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**

None

**Competition Goal**

Students can explain the significance of Sobolev spaces in the theory of partial differential equations. They are able to reproduce and prove the most important properties.

**Content**

Definition of Sobolev spaces for functions on Lipschitz domains, density, continuation and trace theorems, compact embeddings, Helmholtz decomposition, simple applications to partial differential equations.

**Module Grade Calculation**

The grade of the module is the grade of the oral exam.

**Workload**

Total workload: 240 hours  
Attendance: 90 h  
- lectures, problem classes and examination  
Self studies: 150 h  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research on the course content,  
- preparation for the module examination

**Recommendation**

The contents of the module “Functional Analysis” are strongly recommended.
2.190 Module: Software Engineering II [M-INFO-100833]

**Responsible:** Prof. Dr.-Ing. Anne Koziolücke
Prof. Dr. Ralf Reussner

**Organisation:** KIT Department of Informatics

**Part of:** Computer Science

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### Mandatory

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<td>6 CR</td>
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</table>

**Content**

Requirements engineering, software development processes, software quality, software architectures, MDD, Enterprise Software Patterns software maintainability, software security, dependability, embedded software, middleware, domain-driven design
Module: Space and Time Discretization of Nonlinear Wave Equations [M-MATH-105966]

**Responsible:** Prof. Dr. Marlis Hochbruck  
**Organisation:** KIT Department of Mathematics

**Part of:**  
Applied Mathematics (Elective Field Applied Mathematics)  
Mathematical Specialization (Elective Field Mathematical Specialization)  
Additional Examinations

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# 2.192 Module: Spatial Stochastics [M-MATH-102903]

**Responsible:** Prof. Dr. Günter Last  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  

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**Competence Certificate**

The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**

None

**Competence Goal**

The students are familiar with some basic spatial stochastic processes. They do not only understand how to deal with general properties of distributions, but also know how to describe and apply specific models (Poisson process, Gaussian random fields). They know how to work self-organised and self-reflexive.

**Content**

- Random sets
- Point processes
- Random measures
- Palm distributions
- Random fields
- Gaussian fields
- Spectral theory of random fields
- Spatial ergodic theorem

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

Total workload: 240 hours  
Attendance: 90 hours  
- lectures, problem classes, and examination  
Self-studies: 150 hours  
- follow-up and deepening of the course content,  
- work on problem sheets,  
- literature study and internet research relating to the course content,  
- preparation for the module examination

**Recommendation**

The contents of the module Probability Theory are recommended.
Module: Special Topics of Numerical Linear Algebra [M-MATH-102920]

Responsible: Prof. Dr. Marlis Hochbruck
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

Credits: 8
Grading scale: Grade to a tenth
Recurrence: see Annotations
Duration: 1 term
Language: English
Level: 4
Version: 1

Mandatory

| T-MATH-105891 | Special Topics of Numerical Linear Algebra | 8 CR | Grimm, Hochbruck, Neher |

Competence Certificate
The module will be completed by an oral exam (approx. 30 min).

Prerequisites
None.

Competence Goal
At the end of the course, students possess informed knowledge of methods and concepts of numerical linear algebra for large matrices. For various applications, they choose and implement the right numerical methods and they are able to assess and establish convergence properties of these methods. Students are able to solve problems in a self-organized and reflective manner, and to present and discuss solutions.

Content
- Direct methods for sparse linear systems
- Krylov subspace methods for large linear systems and eigenvalue problems
- Matrix functions

Module grade calculation
The module grade is the grade of the oral exam.

Annotation
Bi-yearly course.

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classes, and examination
Self-studies: 150 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
Numerical analysis 1 and 2
Module: Spectral Theory [M-MATH-101768]

**Responsible:** Prof. Dr. Dorothee Frey

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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<td>Spectral Theory - Exam</td>
<td>8 CR Frey, Herzog, Kunstmann, Schnaubelt, Tolksdorf</td>
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</table>

**Competence Certificate**

Oral examination of approx. 30 minutes.

**Prerequisites**

none

**Competence Goal**

After participation, students

- understand the concepts of spectrum and resolvent of closed operators on Banach spaces.
- know their basic properties and are able to explain them in simple examples.
- can explain and justify the special features of compact operators and the Fredholm Alternative.
- can deduce algebraic identities and norm bounds for operators by means of the Dunford functional calculus and the spectral calculus for self-adjoint operators. This in particular includes spectral projections and spectral mapping theorems.
- are able to apply this general theory to integral and differential equations, and recognize the importance of spectral theoretic methods in Analysis.

**Content**

- Closed operators on Banach spaces,
- Spectrum and resolvent,
- Compact operators and Fredholm alternative,
- Dunford functional calculus, spectral projections,
- Fourier transform,
- Unbounded self-adjoint operators on Hilbert spaces,
- Spectral theorem,
- Sesquilinear forms and sectorial operators,
- Applications to partial differential equations.

**Module grade calculation**

The grade of the module is the grade of the oral exam.
Workload
Total workload: 240 hours
Attendance: 90 h
  - lectures, problem classes and examination
Self studies: 150 h
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research on the course content,
  - preparation for the module examination

Recommendation
The module „Functional Analysis“ is strongly recommended.

**Responsible:** Prof. Dr. Michael Plum

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

**Credits** 8

**Grading scale** Grade to a tenth

**Recurrence** Irregular

**Duration** 1 term

**Level** 4

**Version** 1

**Mandatory**

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Plum
2.196 Module: Splitting Methods for Evolution Equations [M-MATH-105325]

Responsible: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)
Additional Examinations

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<td>1 term</td>
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Competence Certificate
The module will be completed by an oral exam (about 30 min).

Prerequisites
None

Competence Goal
After attending the course, students can explain the concept and the advantages of splitting methods. They know important examples of such methods and typical problem classes to which these methods can be applied. They can explain the relation between classical order and accuracy, and they know the (classical) order conditions of such methods. Students can reproduce and explain error estimates for splitting methods for linear and nonlinear evolution equations, and to explain the essential steps of the proof as well as the relevance of the made assumptions.

Content
- Concept and advantages of splitting methods
- Splitting methods for ordinary differential equations
- Baker-Campbell-Hausdorff formula and order conditions
- Tools from operator theory
- Splitting methods for linear evolution equations (Schrödinger equation, parabolic problems)
- Splitting methods for nonlinear evolution equations (nonlinear Schrödinger equation, Gross-Pitaevskii equation, Korteweg-de Vries equation)

Module grade calculation
The module grade is the grade of the oral exam.

Annotation
The module will be offered about every second summer semester.

Workload
Total workload: 180 hours
Attendance: 60 hours
- lectures, problem classes, and examination
Self-studies: 120 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
Familiarity with ordinary differential equations, Runge-Kutta methods (construction, order, stability) and Sobolev spaces (definition, basic properties, Sobolev embeddings) is strongly recommended.
Module: Statistical Learning [M-MATH-105840]

**Responsible:** Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-111726 | Statistical Learning | 8 CR | Trabs |

**Competence Certificate**

The module will be completed with an oral exam (approx. 30 min).

**Prerequisites**

none

**Competence Goal**

At the end of the course, students

- know the fundamental principles and problems of machine learning and can relate learning methods to these,
- are able to explain how selected machine learning methods work and can apply these,
- are able to derive and to discuss a statistical analysis of selected learning methods,
- are able to independently develop and apply new learning methods.

**Content**

The course aims for a rigorous and mathematical analysis of some popular machine learning methods with a focus is on statistical aspects. Topics are:

- **Regression**
  - Empirical risk minimization
  - Lasso
  - Regression trees and Random forests
- **Classification**
  - Bayes classifier
  - model based classifiers (e.g. logistic regression, discriminant analysis)
  - model-free classifiers (e.g. k nearest neighbors, support vector machines)
- **Neural networks**
  - training
  - approximation properties
  - statistical analysis
- **Unsupervised learning**
  - principle component analysis
  - clustering
  - generative models

**Module grade calculation**

The grade of the module is the grade of the oral exam.
Workload
Total workload: 240 hours
Attendance: 90 hours

- lectures, problem classes, and examination

Self-studies: 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The modules "Probability Theory" and "Statistics" (M-MATH-103220) are recommended.
2.198 Module: Statistical Thermodynamics [M-CIWVT-103059]

**Responsible:** Prof. Dr. Sabine Enders

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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<td>Statistical Thermodynamics</td>
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</table>

**Competence Certificate**

Learning control is an oral examination lasting approx. 30 minutes.

**Prerequisites**

Thermodynamics III

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The module M-CIWVT-103058 - Thermodynamics III must have been passed.

**Competence Goal**

The students are able to understand the basics of statistical mechanics and they are able to recognize the advantage and disadvantage for application in chemical engineering.

**Content**

Boltzmann-method, Gibbs-method, real gases, quations of state, polymers

**Module grade calculation**

The module grade is the grade of the oral exam.

**Literature**

# 2.199 Module: Steins Method with Applications in Statistics [M-MATH-105579]

**Responsible:** Dr. rer. nat. Bruno Ebner  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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**Mandatory**

| T-MATH-111187 | Steins Method with Applications in Statistics | 4 CR | Ebner, Hug |

**Prerequisites**

None
2.200 Module: Stochastic Control [M-MATH-102908]

**Responsible:** Prof. Dr. Nicole Bäuerle

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Competence Certificate**

The module will be completed by an oral exam (about 20 min).

**Prerequisites**

none

**Competence Goal**

At the end of the course, students

- can name the mathematical foundations of stochastic control and and are able to apply solution techniques,
- can formulate continuous-time dynamic stochastic optimization problems as stochastic control problems,
- are able to work in a self-organized and reflective manner,

**Content**

- Verification techniques, Hamilton-Jacobi-Bellman equation
- Viscosity solution
- Singular control
- Feynman-Kac representations
- Applications from finance and insurance

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

Total workload: 120 hours

- Attendance: 45 hours
  - lectures, problem classes, and examination
- Self-studies: 75 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**

The course 'Probably Theory' is strongly recommended. The courses 'Brownian motion' and 'Continuous time finance' are recommended.
2.201 Module: Stochastic Differential Equations [M-MATH-102881]

**Responsible:** Prof. Dr. Dorothee Frey

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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<td>Frey, Schnaubelt</td>
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**Content**

- Brownian motion
- Martingales and Martingal inequalities
- Stochastic integrals and Itô's formula
- Existence and uniqueness of solutions for systems of stochastic differential equations
- Perturbation and stability results
- Application to equations in financial mathematics, physics and engineering
- Connection with diffusion equations and potential theory
2.202 Module: Stochastic Geometry [M-MATH-102865]

**Responsible:** Prof. Dr. Daniel Hug  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Applied Mathematics (Elective Field Applied Mathematics)  
- Mathematical Specialization (Elective Field Mathematical Specialization)

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**Mandatory**

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| T-MATH-105840 | Stochastic Geometry | 8 CR | Hug, Last, Winter |

**Competence Certificate**  
The module will be completed by an oral exam (ca. 30 min).

**Prerequisites**  
None

**Competence Goal**  
The students

- know the fundamental geometric models and characteristics in stochastic geometry,  
- are familiar with properties of Poisson processes of geometric objects,  
- know examples of applications of models of stochastic geometry,  
- know how to work self-organised and self-reflexive.

**Content**

- Random Sets  
- Geometric Point Processes  
- Stationarity and Isotropy  
- Germ Grain Models  
- Boolean Models  
- Foundations of Integral Geometry  
- Geometric densities and characteristics  
- Random Tessellations

**Module grade calculation**  
The module grade is the grade of the oral exam.

**Workload**  
Total workload: 240 hours  
Attendance: 90 hours  
- lectures, problem classes, and examination  
Self-studies: 150 hours  
- follow-up and deepening of the course content  
- work on problem sheets  
- literature study and internet research related to the course content  
- preparation for the module exam.

**Recommendation**  
It is recommended to have taken the module 'Spatial Stochastics' beforehand.
## 2.203 Module: Stochastic Information Processing [M-INFO-100829]

**Responsible:** Prof. Dr.-Ing. Uwe Hanebeck  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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**Mandatory**

| T-INFO-101366 | Stochastic Information Processing | 6 CR | Hanebeck |
Module: Stochastic Simulation [M-MATH-106053]

**Responsible:** TT-Prof. Dr. Sebastian Krumscheid  
**Organisation:** KIT Department of Mathematics  
**Part of:** Applied Mathematics (Elective Field Applied Mathematics)  
  Mathematical Specialization (Elective Field Mathematical Specialization)  
**Additional Examinations**

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<td>T-MATH-112242</td>
<td>Stochastic Simulation</td>
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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
None

**Competence Goal**
After successfully taking part in the module's classes and the exam, students will be acquainted with sampling-based computational tools used to analyze systems with uncertainty arising in engineering, physics, chemistry, and economics. Specifically, by the end of this course, students will be able to analyze the convergence of sampling algorithms and implement the discussed sampling methods for different stochastic processes as computer codes. Understanding the advantages and disadvantages of different sampling-based methods, the students can, in particular, choose appropriate stochastic simulation techniques and propose efficient sampling methods for a specific stochastic problem. In particular, they can name and discuss essential theoretical concepts, and understand the structure of the sampling-based computational methods. Finally, the course prepares students to write a thesis in the field of Uncertainty Quantification.

**Content**
The course covers mathematical concepts and computational tools used to analyze systems with uncertainty arising across various application domains. First, we will address stochastic modelling strategies to represent uncertainty in such systems. Then we will discuss sampling-based methods to assess uncertain system outputs via stochastic simulation techniques. The focus of this course will be on the theoretical foundations of the discussed techniques, as well as their methodological realization as efficient computational tools. Topics covered include:

- Random variable generation
- Simulation of random processes
- Simulation of Gaussian random fields
- Monte Carlo method; output analysis
- Variance reduction techniques
- Rare event simulations
- Quasi Monte Carlo methods
- Markov Chain Monte Carlo methods (Metropolis-Hasting, Gibbs sampler)

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
total workload: 150 hours

**Recommendation**
The contents of the modules 'M-MATH-101321 - Introduction to Stochastics' and 'M-MATH-103214 – Numerical Mathematics 1+2' are recommended.
Module: Structural Graph Theory [M-MATH-105463]

Responsible: Prof. Dr. Maria Aksenovich
Organisation: KIT Department of Mathematics
Part of: Mathematical Specialization (Elective Field Mathematical Specialization)

Additional Examinations

Credits 4
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Language English
Level 4
Version 1

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<td>Structural Graph Theory</td>
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Prerequisites

None

Competence Goal

After successful completion of the course, the participants should be able to present and analyse main results in Structural Graph Theory. They should be able to establish connections between graph minors and other graph parameters, give examples, and apply fundamental results to related problems.

Content

The purpose of this course is to provide an introduction to some of the central results and methods of structural graph theory. Our main point of emphasis will be on graph minor theory and the concepts devised in Robertson and Seymour's intricate proof of the Graph Minor Theorem: in every infinite set of graphs there are two graphs such that one is a minor of the other.

Our second point of emphasis (time permitting) will be on Hadwiger's conjecture: that every graph with chromatic number at least \( r \) has a \( K_r \) minor. We shall survey what is known about this conjecture, including some very recent progress.

Recommendation

A solid background in the fundamentals of graph theory.
Module: Supplementary Studies on Culture and Society [M-ZAK-106235]

2.206 Module: Supplementary Studies on Culture and Society [M-ZAK-106235]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
Part of: Additional Examinations

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**Election notes**
With the exception of the final oral exam and the practice module, students have to self-record the achievements obtained in the Supplementary Studies on Culture and Society in their study plan. ZAK records the achievements as "non-assigned" under "UQ/SQ-Leistungen". Further instructions on self-recording of achievements can be found in the FAQ at https://campus.studium.kit.edu/ and on the ZAK homepage at https://www.zak.kit.edu/begleitstudium-bak.php. The title of the examination and the amount of credits override the modules placeholders.

If you want to use ZAK achievements **both for your interdisciplinary qualifications and for the supplementary studies**, please record them in the interdisciplinary qualifications first. You can then get in contact with the ZAK study services (stg@zak.kit.edu) to also record them in your supplementary studies.

In the in-depth module, achievements have to be obtained in three different areas. The areas are as follows:

- Technology & Responsibility
- Doing Culture
- Media & Aesthetics
- Spheres of Life
- Global Cultures

You have to obtain two achievements with 3 credits each and one achievement with 5 credits. To self-record achievements in the in-depth module, you first have to elect the matching partial achievement.

**Note:** If you registered for the Supplementary Studies on Sustainable Development before April 1st, 2023, self-recording an achievement in this module counts as a request in the sense of §20 (2) of the regulations for the Supplementary Studies on Culture and Society. Your overall grade for the supplementary studies will thus be calculated as the average of the examination grades, not as the average of the module grades.

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**Competence Certificate**
The monitoring is explained in the respective partial achievement.
They are composed of:

- minutes
- presentations
- a seminar paper
- an internship report
- an oral examination

After successful completion of the supplementary studies, the graduates receive a graded certificate and a KIT certificate.

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
Prerequisites
The offer is study-accompanying and does not have to be completed within a defined period of time. Enrollment or acceptance for graduation must be present when registering for the final examination.

KIT students register for the supplementary studies by selecting this module in the student portal and self-checking a performance. In addition, registration for the individual courses is necessary, which is possible shortly before the beginning of each semester.

The course catalogue, statutes (study regulations), registration form for the oral exam, and guides for preparing the various written performance requirements can be found as downloads on the ZAK homepage at www.zak.kit.edu/begleitstudium-bak.

Competence Goal
Graduates of the Supplementary Studies on Culture and Society demonstrate a sound basic knowledge of conditions, procedures and concepts for analysing and shaping fundamental social development tasks in connection with cultural topics. They have gained a well-founded theoretical and practical insight into various cultural studies and interdisciplinary topics in the field of tension between culture, technology and society in the sense of an expanded concept of culture.

They are able to place the contents selected from the specialization module in the basic context as well as to analyse and evaluate the contents of the selected courses independently and exemplarily and to communicate about them scientifically in written and oral form. Graduates are able to analyse social topics and problem areas and critically reflect on them in a socially responsible and sustainable perspective.

Content
The Supplementary Studies on Culture and Society can be started from the 1st semester and is not limited in time. It comprises at least 3 semesters. The supplementary studies are divided into 3 modules (basics, in-depth studies, practice). A total of 22 credit points (ECTS) are earned.

The thematic elective areas of the supplementary studies are divided into the following 5 modules and their sub-topics:

**Block 1 Technology & Responsibility**
Value change / ethics of responsibility, technology development / history of technology, general ecology, sustainability

**Block 2 Doing Culture**
Cultural studies, cultural management, creative industries, cultural institutions, cultural policy

**Block 3 Media & Aesthetics**
Media communication, cultural aesthetics

**Block 4 Spheres of Life**
Cultural sociology, cultural heritage, architecture and urban planning, industrial science

**Block 5 Global Cultures**
Multiculturalism / interculturalism / transculturalism, science and culture

Module grade calculation
The overall grade of the supplementary studies is calculated as an average of the grades of the examination performances weighted with credit points.

In-depth Module
- presentation 1 (3 ECTS)
- presentation 2 (3 ECTS)
- seminar paper incl. presentation (5 ECTS)
- oral examination (4 ECTS)
Annotation
With the Supplementary Studies on Culture and Society, KIT provides a multidisciplinary study offer as an additional qualification, with which the respective specialized study program is supplemented by interdisciplinary basic knowledge and interdisciplinary orientation knowledge in the field of cultural studies, which is becoming increasingly important for all professions.

Within the framework of the supplementary studies, students acquire in-depth knowledge of various cultural studies and interdisciplinary subject areas in the field of tension between culture, technology and society. In addition to high culture in the classical sense, other cultural practices, common values and norms as well as historical perspectives of cultural developments and influences are considered.

In the courses, conditions, procedures and concepts for the analysis and design of fundamental social development tasks are acquired on the basis of an expanded concept of culture. This includes everything created by humans - also opinions, ideas, religious or other beliefs. The aim is to develop a modern concept of cultural diversity. This includes the cultural dimension of education, science and communication as well as the preservation of cultural heritage. (UNESCO, 1982)

According to § 16 of the statutes, a reference and a certificate are issued by the ZAK for the supplementary studies. The achievements are also shown in the transcript of records of the degree program and, upon request, in the certificate. They can also be recognized in the interdisciplinary qualifications (see elective information).

Workload
The workload is made up of the recommended number of hours for the individual modules:

- basic module approx. 90 h
- in-depth module approx. 340 h
- practical module approx. 120 h

total: approx. 550 h

Learning type
- lectures
- seminars
- workshops
- practical course

Literature
Recommended reading of primary and specialized literature will be determined individually by each instructor.
2.207 Module: Supplementary Studies on Sustainable Development [M-ZAK-106099]

**Responsible:** Dr. Christine Mielke  
Christine Myglas

**Organisation:** Additional Examinations

- **Credits:** 19
- **Grading scale:** Grade to a tenth
- **Recurrence:** Each term
- **Duration:** 3 terms
- **Language:** German
- **Level:** 4
- **Version:** 1

**Election notes**

With the exception of the final oral exam, students have to self-record the achievements obtained in the Supplementary Studies on Sustainable Development in their study plan. ZAK records the achievements as "non-assigned" under "ÜQ/SQ-Leistungen". Further instructions on self-recording of achievements can be found in the FAQ at [https://campus.studium.kit.edu/](https://campus.studium.kit.edu/) and on the ZAK homepage at [https://www.zak.kit.edu/begleitstudium-bene](https://www.zak.kit.edu/begleitstudium-bene). The title of the examination and the amount of credits override the modules placeholders.

If you want to use ZAK achievements both for your interdisciplinary qualifications and for the supplementary studies, please record them in the interdisciplinary qualifications first. You can then get in contact with the ZAK study services (stg@zak.kit.edu) to also record them in your supplementary studies.

In the elective module, you need to obtain 6 credits worth of achievements in two of the four areas:

- Sustainable Cities & Neighbourhoods
- Sustainable Assessment of Technology
- Subject, Body, Individual: The Other Side of Sustainability
- Sustainability in Culture, Economy & Society

Usually, two achievements with 3 credits each have to be obtained. To self-record achievements in the elective module, you first have to elect the matching partial achievement.

**Note:** If you registered for the Supplementary Studies on Sustainable Development before April 1st, 2023, self-recording an achievement in this module counts as a request in the sense of §19 (2) of the regulations for the Supplementary Studies on Sustainable Development. Your overall grade for the supplementary studies will thus be calculated as the average of the examination grades, not as the average of the module grades.

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Competence Certificate
The monitoring is explained in the respective partial achievement.
They are composed of:
- protocols
- a reflection report
- presentations
- presentations
- the elaboration of a project work
- an individual term paper

Upon successful completion of the supplementary studies, graduates receive a graded report and a certificate issued by ZAK.

Prerequisites
The course is offered during the course of study and does not have to be completed within a defined period of time. Enrolment is required for all performance assessments of the modules of the supplementary studies. Participation in the supplementary studies is regulated by § 3 of the statutes.
KIT students register for the supplementary studies by selecting this module in the student portal and self-booking a performance. Registration for courses, performance assessments and examinations is regulated by § 6 of the Statutes and is usually possible shortly before the beginning of the semester.

The course catalogue, statutes (study regulations), registration form for the oral exam and guidelines for preparing the various written performance requirements can be found as downloads on the ZAK homepage at http://www.zak.kit.edu/begleitstudium-bene.

Competence Goal
Graduates of the supplementary studies in sustainable development acquire additional practical and professional competencies. Thus, the supplementary study program enables the acquisition of basics and initial experience in project management, trains teamwork skills, presentation skills and self-reflection, and also creates a fundamental understanding of sustainability that is relevant for all professional fields.
Graduates are able to analyse social topics and problem areas and critically reflect on them in a socially responsible and sustainable perspective. They are able to place the contents selected from the modules "Elective" and "Advanced" in the basic context as well as to independently and exemplarily analyse and evaluate the contents of the selected courses and to scientifically communicate about them in written and oral form.

Content
The supplementary study program Sustainable Development can be started from the 1st semester and is not limited in time. The wide range of courses offered by ZAK makes it possible to complete the program usually within three semesters. The supplementary studies comprise 19 credit points (LP). It consists of three modules: Basic Module, Elective Module and Advanced Module.
The thematic elective areas of the supplementary studies are divided into the following 4 modules and their subtopics in Module 2 (elective module):

Block 1 Sustainable Cities and Neighbourhoods
The courses provide an overview of the interaction of social, ecological, and economic dynamics in the microcosm of the city.

Block 2 Sustainability Assessment of Technology
Mostly based on ongoing research activities, methods and approaches of technology assessment are elaborated.

Block 3 Subject, Body, Individual: The other Side of Sustainability
Different approaches are presented to the individual perception, experience, shaping and responsibility of relationships to the environment and to oneself.

Block 4 Sustainability in Culture, Economy & Society
Courses usually have an interdisciplinary approach, but may also focus on one of the areas of culture, economics or society, both in application and in theory.

The core of the supplementary studies is a case study in the specialization area. In this project seminar, students conduct sustainability research with practical relevance themselves. The case study is supplemented by an oral examination with two topics from module 2 (elective module) and module 3 (in-depth module).
Module grade calculation
The overall grade of the supplementary studies is calculated as an average of the grades of the examination performances weighted with credit points.

Elective module
- Presentation 1 (3 ECTS)
- Presentation 2 (3 ECTS)

Advanced module
- individual term paper (6 ECTS)
- oral examination (4 ECTS)

Annotation
The Supplementary Studies on Sustainable Development at KIT is based on the conviction that a long-term socially and ecologically compatible coexistence in the global world is only possible if knowledge about necessary changes in science, economy and society is acquired and applied.

The interdisciplinary and transdisciplinary Studies on Sustainable Development enables diverse access to transformation knowledge as well as basic principles and application areas of sustainable development. According to the statutes § 16, a certificate is issued by the ZAK for the complementary studies.

The achievements are also shown in the transcript of records of the degree program and, upon request, in the certificate. They can also be recognized in the interdisciplinary qualifications (see elective information).

In the specialised studies, modules and partial achievements can be recognised within the framework of the additional achievements or e.g. the interdisciplinary qualifications. This must be regulated via the respective subject study programme.

The focus is on experience- and application-oriented knowledge and competences, but theories and methods are also learned. The aim is to be able to represent one's own actions as a student, researcher and later decision-maker as well as an individual and part of society under the aspect of sustainability.

Sustainability is understood as a guiding principle to which economic, scientific, social and individual actions should be oriented. According to this, the long-term and socially just use of natural resources and the material environment for a positive development of global society can only be addressed by means of integrative concepts. Therefore, "education for sustainable development" in the sense of the United Nations programme plays just as central a role as the goal of promoting "cultures of sustainability". For this purpose, practice-centred and research-based learning of sustainability is made possible and the broad concept of culture established at ZAK is used, which understands culture as habitual behaviour, lifestyle and changing context for social actions.

The supplementary study programme conveys the basics of project management, trains teamwork skills, presentation skills and self-reflection. Complementary to the specialised studies at KIT, it creates a fundamental understanding of sustainability, which is important for all professional fields. Integrative concepts and methods are essential: in order to use natural resources in the long term and to shape the global future in a socially just way, not only different disciplines, but also citizens, practitioners and institutions must work together.

Workload
The workload is made up of the number of hours of the individual modules:

- Basic module approx. 180 h
- Elective module approx. 150 h
- Consolidation module approx. 180 h

Total: approx. 510 h

Learning type
- lectures
- seminars
- workshops

Literature
Recommended reading of primary and specialist literature is determined individually by the respective lecturer.
# 2.208 Module: Technical Optics [M-ETIT-100538]

**Responsible:** Prof. Dr. Cornelius Neumann  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** Electrical Engineering / Information Technology (Electrical Engineering / Information Technology)

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**Prerequisites**

none
**2.209 Module: Technomathematical Seminar [M-MATH-102863]**

**Responsible:** PD Dr. Stefan Kühnlein  
**Organisation:** KIT Department of Mathematics  
**Part of:**  
- Experimental Physics (mandatory)  
- Wildcard Technical Field  
- Electrical Engineering / Information Technology (mandatory)  
- Chemical and Process Engineering (mandatory)

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<td>Each term</td>
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</table>

**Mandatory**

| T-MATH-105884 | Technomathematical Seminar | 3 CR | Jahnke, Kühnlein |

**Prerequisites**  
None

**Competence Goal**  
At the end of the module, the participants can

- analyze a specific problem in a scientific area  
- discuss, present and defend subject-specific problems in the given context  
- summarize the most important results concerning the topic

They have communicative, organizational and didactical skills in complex problem analyses at their disposal. They can apply techniques of scientific work.

**Content**  
The technomathematical seminar optionally can be completed in mathematics, in computer sciences or in the technical subject. The specific content depends on the offered seminar courses. The chosen topic must possess a significant connection to applications. Admissible are seminar talks of at least 45 minutes as in the other mathematical seminar courses as well as the treatment of small projects with a project report and short presentation at the end, for instance in the technical field.

**Workload**  
Total work load: 90 minutes.  
The specific workload in attendance and self studies depends on the specific choice.
### Module: Telematics [M-INFO-100801]

**Responsible:** Prof. Dr. Martina Zitterbart  
**Organisation:** KIT Department of Informatics  
**Part of:** Computer Science

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<tr>
<td>T-INFO-101338 <strong>Telematics</strong></td>
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**Competence Certificate**  
See partial achievement.

**Prerequisites**  
See partial achievement.

**Competence Goal**

Students

- master protocols, architectures, and methods and algorithms that are used on the Internet for routing and for establishing a reliable end-to-end connection, as well as various media allocation procedures in local networks.  
- have an understanding of the systems and the problems that appear in a global, dynamic network as well as the mechanisms used to remedy them.  
- are familiar with current developments such as SDN and data center networking.  
- know methods to manage and administrate networks.

Students master the basic protocol mechanisms for establishing reliable end-to-end communication. Students have detailed knowledge of the mechanisms used in TCP for congestion and flow control and can discuss the issue of fairness with multiple parallel transport streams. Students can analytically determine the performance of transport protocols and know methods that fulfill special requirements of TCP, such as high data rates and short latencies. Students are familiar with current topics such as problems introduced by utilization of middle boxes in the Internet, the use of TCP in data centers and multipath TCP. Students can use transport protocols in practice.

Students know the functions of routers in the Internet and can reproduce and apply common routing algorithms. Students can reproduce the architecture of a router and know different approaches to buffer placement as well as their advantages and disadvantages.

Students understand the distinction of routing protocols into interior and exterior gateway protocols and have detailed knowledge of the functionality and properties of common protocols such as RIP, OSPF and BGP. The students are familiar with current topics such as SDN.

Students know the function of media allocation and can classify and analytically evaluate media allocation processes. Students have in-depth knowledge of Ethernet and are familiar with various Ethernet forms and their differences, especially current developments such as real-time Ethernet and data center Ethernet. Students can reproduce and apply the spanning tree protocol.

Students can reproduce the technical characteristics of DSL. Students are familiar with the concept of label switching and can compare existing approaches such as MPLS.

**Content**

- Introduction  
- End-to-end data transport  
- Routing protocols and architectures  
- Media allocation  
- Bridges  
- Data transmission  
- Further selected examples  
- Network management

**Workload**

180 hrs.
2.211 Module: Theoretical Nanooptics [M-PHYS-102295]

Responsible: Prof. Dr. Markus Garst
              Prof. Dr. Carsten Rockstuhl

Organisation: KIT Department of Physics
Part of: Experimental Physics (Experimental Physics)

Credits 6
Grading scale Grade to a tenth
Recurrence Irregular
Duration 1 term
Language English
Level 4
Version 1

Mandatory
T-PHYS-104587 Theoretical Nanooptics 6 CR Garst, Rockstuhl

Competence Certificate
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

Prerequisites
none

Competence Goal
The properties of light at the nanoscale can be controlled by various means. The aim of this lecture is to familiarize the students with the different possibilities that rely on nanostructured dielectric or metallic materials and to outline on solid mathematical grounds the analytical description of observable effects. The lecture is meant as a complementary source of education to experimental lecture. It shall provide the students with the necessary skills to work themselves in the field of theoretical nanooptics.

Content
- Dispersion relation to describe light in extended systems such as free space, interfaces, planar waveguides and waveguides with complicated geometrical cross sections.
- Description of the interaction of light with isolated objects such as spheres, cylinders, ellipsoids and prolates and oblates.
- Properties of plasmonic nanoparticles and the ability to tune their properties
- Notion of optical antennas and the discussion of their basic characteristics
- Description of the dynamics of wave propagation by perturbed eigenstates, i.e. coupled mode theory. Application to optical waveguide arrays.
- Discussion of metamaterials (unit cells, homogenization, light propagation, applications)
- Transformation optics
- Analytical modeling and phenomenological tools to describe nanooptical systems

Workload
180 hours composed of active time (45), wrap-up of the lecture incl. preparation of the examination and the exercises (135)

Recommendation
Solid mathematical background, good knowledge of classical electromagnetism and theoretical optics.

Literature
- L. Novotny and B. Hecht, Principle of Nano-Optics, Cambridge
- S. A. Maier, Plasmonics, Springer
2.212 Module: Theoretical Optics [M-PHYS-102277]

**Responsible:** PD Dr. Boris Narozhnyy  
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** Experimental Physics (Experimental Physics)

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**Mandatory**

| T-PHYS-104578 | Theoretical Optics | 6 CR | Narozhnyy, Rockstuhl |

**Competence Certificate**

Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**

none

**Competence Goal**

The students deepen their knowledge about the theory and the mathematical tools in optics and photonics. They learn how to apply these tools to describe fundamental phenomena and how to predict observable quantities that reflect the actual physics from the theory by way of a corresponding purposeful mathematical analyses. They learn how to solve problems of both, interpretative and predictive nature with regards to model systems and real life situations.

**Content**

- Review of Electromagnetism (Maxwell’s Equations, Stress Tensor, Material Properties, Kramers-Kronig Relation, Wave Propagation, Poynting’s Theorem)
- Crystal Optics (Polarization, Anisotropic Media, Fresnel Equation, Applications)
- Classical Coherence Theory (Elementary Coherence Phenomena, Theory of Stochastic Processes, Correlation Functions)
- Quantum Optics and Quantum Optical Coherence Theory (Review of Quantum Mechanics, Quantization of the EM Field, Quantum Coherence Functions)

**Annotation**

For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation numbers and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

**Workload**

180 hours composed of active time (45 hours), wrap-up of the lecture incl. preparation of the examination (135 hours)

**Recommendation**

Solid mathematical background, good knowledge of classical electromagnetism and basic knowledge of quantum mechanics.

**Literature**

- "Classical Electrodynamics" John David Jackson
- "Theoretical Optics: An Introduction" Hartmann Römer
- "Introduction to Fourier Optics" Joseph W. Goodman
- "Introduction to the Theory of Coherence and Polarization of Light" Emil Wolf
- "The Quantum Theory of Light " Rodney Loudon
2.213 Module: Thermodynamics III [M-CIWVT-103058]

**Responsible:** Prof. Dr. Sabine Enders

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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<td>Thermodynamics III</td>
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**Competence Certificate**

Learning control is a written examination lasting 90 minutes.

**Prerequisites**

None

**Competence Goal**

Students are familiar with the basic principles for the description of complex, multicomponent mixtures and thermodynamic equilibria including equilibria with chemical reactions. They are able to select suitable models and to calculate the properties of multicomponent real systems.

**Content**

Phase- and reaction equilibria of real systems, equations of state for real mixtures, models for activity coefficients, polymer solutions, protein solutions, electrolyte solutions.

**Module grade calculation**

The module grade is the grade of the written exam.

**Workload**

- Attendance time (Lecture): 60 h
- Homework: 90 h
- Exam Preparation: 30 h

**Literature**

M 2.214 Module: Thermodynamics of Interfaces [M-CIWVT-103063]

**Responsible:** Prof. Dr. Sabine Enders

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** Chemical and Process Engineering (Chemical and Process Engineering)

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<td>Thermodynamics of Interfaces</td>
<td>4 CR Enders</td>
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</table>

**Competence Certificate**

Learning control is an oral examination lasting approx. 30 minutes.

**Prerequisites**

None

**Competence Goal**

The students to be familiar with the peculiarities on fluid-fluid and fluid-solid interfacial properties. They are able to calculate interfacial properties (interfacial tension, density - and concentration profiles, adsorption isotherms) using macroscopic and local-dependent methods.

**Content**

Gibbs-method, density functional theory, experimental methods for characterization of interfaces, adsorption

**Module grade calculation**

The module grade is the grade of the oral exam.
2.215 Module: Time Series Analysis [M-MATH-102911]

**Responsible:** PD Dr. Bernhard Klar

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Mandatory**

| T-MATH-105874 | Time Series Analysis | 4 CR | Ebner, Fasen-Hartmann, Gneiting, Klar, Trabs |

**Competence Certificate**
The module will be completed by an oral exam (ca. 20 min).

**Prerequisites**
None

**Competence Goal**
At the end of the course, students will
- know and understand the standard models of time series analysis,
- know exemplary statistical methods for model selection and model validation,
- independently apply models and methods from the lecture to real and simulated data,
- know specific mathematical techniques and be able to use them to analyze time series models.

**Content**
The lecture covers the basic concepts of classical time series analysis:
- Stationary time series
- Trends and seasonality
- Autocorrelation
- Autoregressive models
- ARMA models
- Parameter estimation
- Forecasting
- Spectral density and periodogram

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Total workload: 120 hours
- Attendance: 45 hours
- - lectures, problem classes, and examination
- Self-studies: 75 hours
- - follow-up and deepening of the course content,
- - work on problem sheets,
- - literature study and internet research relating to the course content,
- - preparation for the module examination

**Recommendation**
The contents of the course "Probability Theory" are strongly recommended. The contents of the course "Statistics" are recommended.
### 2.216 Module: Topological Data Analysis [M-MATH-105487]

**Responsible:** Prof. Dr. Tobias Hartnick  
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:**  
- Applied Mathematics (Analysis)  
- Mathematical Specialization (Elective Field Mathematical Specialization)

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<td>Topological Data Analysis</td>
<td>6 CR</td>
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</table>

Hartnick, Sauer
2.217 Module: Topological Genomics [M-MATH-106064]

**Responsible:** Dr. Andreas Ott

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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**Mandatory**

| T-MATH-112281 | Topological Genomics | 3 CR | Ott |

**Competence Certificate**
oral exam of ca. 20 min

**Prerequisites**
None

**Module grade calculation**
The grade of the module is the grade of the oral exam.

**Workload**
total workload: 90 hours
2.218 Module: Translation Surfaces [M-MATH-105973]

**Responsible:** Prof. Dr. Frank Herrlich

**Organisation:** KIT Department of Mathematics

**Part of:** Mathematical Specialization (Elective Field Mathematical Specialization)

**Additional Examinations**

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**Mandatory**

| T-MATH-112128 | Translation Surfaces | 8 CR | Herrlich |

**Competence Certificate**

The module will be completed by an oral exam of about 30 min.

**Prerequisites**

None

**Competence Goal**

At the end of the module, participants are able to

- name and discuss basic concepts to study translation surfaces,
- describe and use in examples essential methods for the classification of translation surfaces,
- read recent research papers on translation surfaces and write a thesis in this field.

**Content**

- Characterization of finite translation surfaces
- Riemann surfaces and algebraic curves
- Moduli space of Riemann surfaces
- Classification of translation surfaces
- Strata and the action of SL(2,R)
- Period coordinates

**Module grade calculation**

The module grade is the grade of the oral exam.

**Workload**

Total workload: 240 hours

- Attendance: 90 hours
  - lectures, problem classes, and examination

- Self-studies: 150 hours
  - follow-up and deepening of the course content,
  - work on problem sheets,
  - literature study and internet research relating to the course content,
  - preparation for the module examination

**Recommendation**

Basic knowledge in surface topology and complex analysis is strongly recommended. The module "Algebraic Geometry" is also recommended.
2.219 Module: Traveling Waves [M-MATH-102927]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

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<td>Traveling Waves</td>
<td>6</td>
<td>English</td>
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**Competence Certificate**
The module examination takes place in form of an oral exam of about 30 minutes. Please see under "Modulnote" for more information about the bonus regulation.

**Prerequisites**
none

**Competence Goal**
After successful completion of this module students:

- can explain the significance of traveling waves and their dynamic stability;
- know basic methods to study the existence of traveling waves;
- outline the main steps in a stability analysis and address potential complications;
- have acquired several mathematical tools to compute or approximate the spectrum;
- master several techniques to derive (in)stability of the wave from spectral information;
- understand how spectrum and stability might depend on the class of perturbations.

**Content**
Traveling waves are solutions to nonlinear partial differential equations (PDEs) that propagate over time with a fixed speed without changing their profiles. These special solutions arise in many applied problems where they model, for instance, water waves, nerve impulses in axons or light in optical fibers. Therefore, their existence and the naturally associated question of their dynamic stability is of interest, because only those waves which are stable can be observed in practice.

The first step in the stability analysis is to linearize the underlying PDE about the wave and compute the associated spectrum, which is in general a nontrivial task. To approximate spectra associated with various waves, such as fronts, pulses and periodic wave trains, we introduce the following tools:

- Sturm-Liouville theory
- exponential dichotomies
- Fredholm theory
- the Evans function
- parity arguments
- essential spectrum, point spectrum and absolute spectrum
- exponential weights

The next step is to derive useful bounds on the linear solution operator, or semigroup, based on the spectral information. A complicating factor is that any non-constant traveling wave possesses spectrum up to the imaginary axis. For various dissipative PDEs, such as reaction-diffusion systems, we employ the bounds on the linear solution operator to close a nonlinear argument via iterative estimates on the Duhamel formula. For traveling waves in Hamiltonian PDEs, such as the NLS or KdV equation, we describe a different route towards stability based on the variational arguments of Grillakis, Shatah and Strauss.

**Module grade calculation**
After passing the oral exam at the end of the semester, the final grade is \( \min(0.7X + 0.3Y, X) \), where \( X \) is the grade for the oral exam and \( Y \) is the grade obtained by voluntarily working out and presenting a model problem during one of the exercise classes.
Workload
Total workload: 180 hours
Attendance: 60 hours
  • lectures, problem classes, and examination
Self-studies: 120 hours
  • follow-up and deepening of the course content,
  • work on problem sheets,
  • literature study and internet research relating to the course content,
  • preparation for the module examination

Recommendation
The following background is strongly recommended: Analysis 1-4.

Literature
2.220 Module: Uncertainty Quantification [M-MATH-104054]

Responsible: Prof. Dr. Martin Frank
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
           Mathematical Specialization (Elective Field Mathematical Specialization)
           Additional Examinations

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<td>Each summer term</td>
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Mandatory

| T-MATH-108399 | Uncertainty Quantification | 4 CR | Frank |

Prerequisites
None

Competence Goal
After successfully taking part in the module's classes and exams, students have gained knowledge and abilities as described in the "Inhalt" section.

Specifically, students know several parametrization methods for uncertainties. Furthermore, students are able to describe the basics of several solution methods (stochastic collocation, stochastic Galerkin, Monte-Carlo). Students can explain the so-called curse of dimensionality.

Students are able to apply numerical methods to solve engineering problems formulated as algebraic or differential equations with uncertainties. They can name the advantages and disadvantages of each method. Students can judge whether specific methods are applicable to the specific problem and discuss their results with specialists and colleagues. Finally, students are able to implement the above methods in computer codes.

Content
In this class, we learn to propagate uncertain input parameters through differential equation models, a field called Uncertainty Quantification (UQ). Given uncertain input (parameter values, initial or boundary conditions), how uncertain is the output? The first part of the course ("how to do it") gives an overview on techniques that are used. Among these are:

- Sensitivity analysis
- Monte-Carlo methods
- Spectral expansions
- Stochastic Galerkin method
- Collocation methods, sparse grids

The second part of the course ("why to do it like this") deals with the theoretical foundations of these methods. The so-called "curse of dimensionality" leads us to questions from approximation theory. We look back at the very standard numerical algorithms of interpolation and quadrature, and ask how they perform in many dimensions.

Recommendation
Numerical methods for differential equations
Module: Variational Methods [M-MATH-105093]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:**
- Applied Mathematics (Analysis)
- Applied Mathematics (Elective Field Applied Mathematics)
- Mathematical Specialization (Elective Field Mathematical Specialization)
- Additional Examinations

**Credits:** 8

**Grading scale:** Grade to a tenth

**Recurrence:** Irregular

**Duration:** 1 term

**Level:** 4

**Version:** 1

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**Competence Certificate**
The module will be completed by an oral exam (ca. 30 min).

**Competence Goal**
Graduates will be able to:

- assess the significance of variational problems in relation to their applications in the natural sciences, engineering or geometry and illustrate them using examples,
- formulate variational problems independently,
- recognize the specific difficulties within the calculus of variations,
- analyze and solve concrete, prototypical problems,
- use techniques to prove the existence of solutions to certain classes of variational problems and calculate these solutions in special cases.

**Content**

- one-dimensional variational problems
- Euler-Lagrange equation
- necessary and sufficient criteria
- multidimensional variational problems
- direct methods of the calculus of variations
- existence of critical points of functionals

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**

Total workload: 240 hours

**Attendance:** 90 hours

- lectures, problem classes, and examination

**Self-studies:** 150 hours

- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

**Recommendation**
The contents of the courses Functional Analysis, Classical Methods for Partial Differential Equations, or Boundary and Eigenvalue problems are recommended.
Module: Wavelets [M-MATH-102895]

Responsible: Prof. Dr. Andreas Rieder
Organisation: KIT Department of Mathematics
Part of: Applied Mathematics (Elective Field Applied Mathematics)
Mathematical Specialization (Elective Field Mathematical Specialization)

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Mandatory

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<td>T-MATH-105838</td>
<td>Wavelets</td>
<td>8 CR</td>
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Competence Certificate
Success is assessed in the form of an oral examination lasting approx. 30 minutes.

Prerequisites
none

Competence Goal
Graduates are able
- to name, discuss and analyze the functional-analytical principles of continuous and discrete wavelet transforms,
- to apply the wavelet transform as an analysis tool in signal and image processing and evaluate the results obtained,
- to explain design aspects for wavelet systems.

Content
- Short-time Fourier transform
- Integral wavelet transform
- Wavelet frames
- Wavelet basis
- Fast wavelet transform
- Construction of orthogonal and bi-orthogonal wavelet systems
- Applications in signal and image processing

Module grade calculation
The module grade is the grade of the oral exam.

Workload
Total workload: 240 hours
Attendance: 90 hours
- lectures, problem classes, and examination
Self-studies: 150 hours
- follow-up and deepening of the course content,
- work on problem sheets,
- literature study and internet research relating to the course content,
- preparation for the module examination

Recommendation
The course “Functional analysis” is recommended.
3 Courses

3.1 Course: Adaptive Finite Element Methods [T-MATH-105898]

Responsible: Prof. Dr. Willy Dörfler
Organisation: KIT Department of Mathematics
Part of: M-MATH-102900 - Adaptive Finite Elemente Methods

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Events

| ST 2024 | 0160610 | Tutorial for 0160600 (Numerical Methods in Fluidmechanics) | 1 SWS | Practice | Dörfler |

Prerequisites

none
3.2 Course: Advanced Inverse Problems: Nonlinearity and Banach Spaces [T-MATH-105927]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102955 - Advanced Inverse Problems: Nonlinearity and Banach Spaces

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**Prerequisites**

none
### 3.3 Course: Algebra [T-MATH-102253]

**Responsible:** PD Dr. Stefan Kühnlein  
Prof. Dr. Roman Sauer  

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-101315 - Algebra

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<td>Algebra</td>
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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
3.4 Course: Algebraic Geometry [T-MATH-103340]

**Responsible:** Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-101724 - Algebraic Geometry

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<th>Lecture</th>
<th>Herrlich</th>
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<td>0152010</td>
<td>Übungen zu 0152000 (Algebraische Geometrie)</td>
<td>2 SWS</td>
<td>Practice</td>
<td>Herrlich</td>
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</table>
### 3.5 Course: Algebraic Number Theory [T-MATH-103346]

**Responsible:** Prof. Dr. Frank Herrlich  
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-101725 - Algebraic Number Theory

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**Competence Certificate**  
oral examination of ca. 30 minutes

**Prerequisites**  
none
3.6 Course: Algebraic Topology [T-MATH-105915]

**Responsible:** TT-Prof. Dr. Manuel Krannich
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102948 - Algebraic Topology

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**Prerequisites**
none
3.7 Course: Algebraic Topology II [T-MATH-105926]

**Responsible:** Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102953 - Algebraic Topology II

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**Prerequisites**
none
# 3.8 Course: Analytical and Numerical Homogenization [T-MATH-111272]

**Responsible:** Prof. Dr. Marlis Hochbruck  
TT-Prof. Dr. Roland Maier  

**Organisation:**  
KIT Department of Mathematics  

**Part of:**  
M-MATH-105636 - Analytical and Numerical Homogenization

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## Events

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## Exams

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<td>Analytical and Numerical Homogenization</td>
<td>Maier</td>
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## Prerequisites

none
3.9 Course: Applications of Topological Data Analysis [T-MATH-111290]

**Responsible:** Dr. Andreas Ott  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105651 - Applications of Topological Data Analysis

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**Prerequisites**  
none
3.10 Course: Aspects of Geometric Analysis [T-MATH-106461]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-103251 - Aspects of Geometric Analysis

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**Events**

| ST 2024 | 0176600 | AG Geometrische Analysis | 2 SWS | Seminar | Lamm |

**Prerequisites**

Keine
### 3.11 Course: Astroparticle Physics I [T-PHYS-102432]

**Responsible:** Prof. Dr. Guido Drexlin
Prof. Dr. Kathrin Valerius

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102075 - Astroparticle Physics I

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Legend: 🖥 Online, ☑️ Blended (On-Site/Online), 🗣️ On-Site, X Cancelled

**Prerequisites**
none
3.12 Course: Banach Algebras [T-MATH-105886]

**Responsible:** PD Dr. Gerd Herzog

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102913 - Banach Algebras

**Type**
Oral examination

**Credits**
3

**Grading scale**
Grade to a third

**Version**
1

**Prerequisites**
none
3.13 Course: Basics Module - Self Assignment BAK [T-ZAK-112653]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
**Part of:** M-ZAK-106235 - Supplementary Studies on Culture and Society

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**Competence Certificate**
The monitoring in this module includes a course credit according to § 5 section 4 in the form of minutes of which two are to be handed in freely chosen topics of the lecture series "Introduction to Applied Studies on Culture and Society". Length: approx. 6,000 characters each (incl. spaces).

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**

**Annotation**
The Basic Module consists of the lecture "Introduction to Supplementary Studies on Culture and Society", which is offered only in the winter semester. It is therefore recommended that students start their studies in the winter semester and complete them before module 2.
3.14 Course: Basics Module - Self Assignment BeNe [T-ZAK-112345]

**Responsible:** Christine Myglas

**Organisation:**
- **Part of:** M-ZAK-106099 - Supplementary Studies on Sustainable Development

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<td>pass/fail</td>
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**Competence Certificate**
The monitoring in this module includes a course credit according to § 5 section 4:

Introduction to Sustainable Development in the form of minutes of which two are to be handed in freely chosen topics of the lecture series "Introduction to Sustainable Development". Length: approx. 6,000 characters each (incl. spaces).

or

Sustainability Spring Days at KIT in the form of a reflection report on all components of the project days "Sustainability Spring Days at KIT". Length approx. 12,000 characters (incl. spaces).

**Prerequisites**
None

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**

**Annotation**
Module Basics consists of the lecture "Introduction to Sustainable Development", which is only offered in the summer semester or alternatively of the project days "Sustainability Spring Days at KIT", which is only offered in the winter semester. It is recommended to complete the course before Elective Module an Specialisation Module.

In exceptional cases, Elective Module or Specialisation Module can also be completed simultaneously with Basics Module. However, the prior completion of the advanced modules Elective and Specialisation should be avoided.
3.15 Course: Basics of Nanotechnology I [T-PHYS-102529]

Responsible: apl. Prof. Dr. Gernot Goll
Organisation: KIT Department of Physics
Part of: M-PHYS-102097 - Basics of Nanotechnology I

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Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

Prerequisites
none
### 3.16 Course: Basics of Nanotechnology II [T-PHYS-102531]

**Responsible:** apl. Prof. Dr. Gernot Goll  
**Organisation:** KIT Department of Physics  
**Part of:** M-PHYS-102100 - Basics of Nanotechnology II

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Legend: 🖥 Online, ☑️ Blended (On-Site/Online), 🗂 On-Site, ✗ Cancelled

**Prerequisites**
none
3.17 Course: Batteries and Fuel Cells [T-ETIT-100983]

**Responsible:** Prof. Dr.-Ing. Ulrike Krewer

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-100532 - Batteries and Fuel Cells

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<td>Krewer, Lindner</td>
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**Exams**

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Legend:  🧩 Online,  🧩 Blended (On-Site/Online),  🗣 On-Site,  ❌ Cancelled

**Prerequisites**

none

Below you will find excerpts from events related to this course:

**Batteries and Fuel Cells**

2304207, WS 23/24, 2 SWS, Language: German, [Open in study portal](https://ilias.studium.kit.edu/goto.php?target=crs_2193746&client_id=produktiv)

**Content**

The lecture provides a practical insight into the current application areas and research topics of fuel cells and batteries. It deals with the design and functionality of electrochemical energy conversion and storage devices and provides knowledge about materials, cell designs, measurement methods, data analysis and modelling. The lecture and most slides are in German.

**Organizational issues**

3.18 Course: Bayesian Inverse Problems with Connections to Machine Learning [T-MATH-112842]

**Responsible:** TT-Prof. Dr. Sebastian Krumscheid

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106328 - Bayesian Inverse Problems with Connections to Machine Learning

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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
none
3.19 Course: Bifurcation Theory [T-MATH-106487]

**Responsible:** Dr. Rainer Mandel  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103259 - Bifurcation Theory

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**Prerequisites**  
None
3.20 Course: Biopharmaceutical Purification Processes [T-CIWVT-106029]

**Responsible:** Prof. Dr. Jürgen Hubbuch

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** M-CIWVT-103065 - Biopharmaceutical Purification Processes

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<td>Lecture / 🗣</td>
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**Competence Certificate**

The examination is a written examination with a duration of 120 minutes (section 4 subsection 2 number 1 SPO).
3.21 Course: Bott Periodicity [T-MATH-108905]

**Responsible:** Prof. Dr. Wilderich Tuschmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-104349 - Bott Periodicity

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**Prerequisites**
none
Below you will find excerpts from events related to this course:

**Boundary and Eigenvalue Problems**

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**Exams**

| WT 23/24 | 0100032 | Boundary and Eigenvalue Problems | Anapolitanos, Lamm, Hundertmark, Liao, Lewintan |

**Content**

We consider boundary value and eigenvalue problems within mathematics and physics, describe qualitative properties of solutions, prove the existence of solutions to boundary value problems using functional analytical methods and will work in more general function spaces, e.g. Sobolev spaces. Further contents are the weak formulation of 2nd order linear elliptic equations, existence and regularity theory of elliptic equations, as well as, eigenvalue theory for weakly formulated elliptic eigenvalue problems.
3.23 Course: Boundary Element Methods [T-MATH-109851]

Responsible: PD Dr. Tilo Arens
Organisation: KIT Department of Mathematics
Part of: M-MATH-103540 - Boundary Element Methods

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Prerequisites
none
3.24 Course: Boundary Value Problems for Nonlinear Differential Equations
[T-MATH-105847]

**Responsible:** Prof. Dr. Michael Plum
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102876 - Boundary value problems for nonlinear differential equations

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### 3.25 Course: Brownian Motion [T-MATH-105868]

**Responsible:** Prof. Dr. Nicole Bäuerle
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Günter Last

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102904 - Brownian Motion

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**Prerequisites**

none
### 3.26 Course: Classical Methods for Partial Differential Equations [T-MATH-105832]

**Responsible:**
- Prof. Dr. Dorothee Frey
- Prof. Dr. Dirk Hundertmark
- Prof. Dr. Tobias Lamm
- Prof. Dr. Michael Plum
- Prof. Dr. Wolfgang Reichel
- Prof. Dr. Roland Schnaubelt

**Organisation:**
KIT Department of Mathematics

**Part of:**
M-MATH-102870 – Classical Methods for Partial Differential Equations

**Type**
- Written examination

**Credits**
- 8

**Grading scale**
- Grade to a third

**Version**
- 1

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### 3.27 Course: Cognitive Systems [T-INFO-101356]

**Responsible:** Prof. Dr. Gerhard Neumann  
Prof. Dr. Alexander Waibel

**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100819 - Cognitive Systems

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**Events**

| WT 23/24 | 2400158 | Introduction to Artificial Intelligence | 3 SWS | Lecture / Practice ( / ) | Neumann, Friederich |

**Exams**

| WT 23/24 | 7500321 | Introduction to Artificial Intelligence with Additional Performances | Neumann, Friederich |

**Legend:** 🖥 Online, 🧩 Blended (On-Site/Online), 🗿 On-Site, 🗿 Cancelled
### 3.28 Course: Combinatorics [T-MATH-105916]

**Responsible:** Prof. Dr. Maria Aksenovich  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102950 - Combinatorics

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**Prerequisites**

none

**Annotation**
The course is offered every second year.

---

Below you will find excerpts from events related to this course:

**Combinatorics**  
0150300, SS 2024, 4 SWS, Open in study portal

**Content**

Combinatorics is an area of mathematics primarily concerned with counting finite structures such as sets, groups, and graphs. While combinatorial problems are often very basic and easy to describe, solving them requires special knowledge and skills. This course is devoted to main concepts and techniques in combinatorics. These include counting principles such as inclusion-exclusion and bijective mappings, twelfold way, generating functions, arrangements, Young tableaux, partitions, recursions, partially ordered sets, extremal set theory, and combinatorial designs.
### 3.29 Course: Combustion Technology [T-CIWVT-106104]

**Responsible:** Prof. Dr.-Ing. Dimosthenis Trimis  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103069 - Combustion Technology

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**Exams**

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**Legend:** 🖥 Online, 📈 Blended (On-Site/Online), 🗣 On-Site, ❌ Cancelled

**Prerequisites**

None
3.30 Course: Comparison Geometry [T-MATH-105917]

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Prerequisites
Keine
### 3.31 Course: Complex Analysis [T-MATH-105849]

**Responsible:**
- PD Dr. Gerd Herzog
- Prof. Dr. Michael Plum
- Prof. Dr. Wolfgang Reichel
- Prof. Dr. Roland Schnaubelt
- Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102878 - Complex Analysis

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3.32 Course: Compressive Sensing [T-MATH-105894]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102935 - Compressive Sensing

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### 3.33 Course: Computational Fluid Dynamics [T-CIWVT-106035]

**Responsible:** Prof. Dr.-Ing. Hermann Nirschl  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103072 - Computational Fluid Dynamics

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**Legend:**  
🖥 Online,  
🧩 Blended (On-Site/Online),  
🗣 On-Site,  
🗙 Cancelled

**Competence Certificate**

Learning control is a written examination lasting 90 minutes.

**Prerequisites**

None
3.34 Course: Computational Fluid Dynamics and Simulation Lab [T-MATH-113373]

**Responsible:** PD Dr. Mathias Krause
PD Dr. Gudrun Thäter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106634 - Computational Fluid Dynamics and Simulation Lab

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**Prerequisites**
none
3.35 Course: Computer Architecture [T-INFO-101355]

**Responsible:**  Prof. Dr. Wolfgang Karl

**Organisation:**  KIT Department of Informatics

**Part of:**  M-INFO-100818 - Computer Architecture

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled
3.36 Course: Computer Graphics [T-INFO-101393]

**Responsible:** Prof. Dr.-Ing. Carsten Dachsbacher

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100856 - Computer Graphics

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**Exams**

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Legend: 🖥 Online, 🛠 Blended (On-Site/Online), 🔒 On-Site, ✗ Cancelled
### 3.37 Course: Computer Graphics Pass [T-INFO-104313]

**Responsible:** Prof. Dr.-Ing. Carsten Dachsbacher  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100856 - Computer Graphics

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**Events**

| WT 23/24 | 24083 | Übungen zu Computergrafik | Lecture / Practice (Bretl, Dolp, Piochowiak)

**Exams**

| WT 23/24 | 7500508 | Computer Graphics | Dachsbacher |

**Responsible:** Prof. Dr. Michael Plum  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102883 - Computer-Assisted Analytical Methods for Boundary and Eigenvalue Problems

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3.39 Course: Condensed Matter Theory I, Fundamentals [T-PHYS-102559]

**Responsible:** Prof. Dr. Markus Garst  
Prof. Dr. Alexander Mirlin  
Prof. Dr. Alexander Shnirman

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102054 - Condensed Matter Theory I, Fundamentals

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled

**Prerequisites**

none
3.40 Course: Condensed Matter Theory I, Fundamentals and Advanced Topics
[T-PHYS-102558]

Responsible: Prof. Dr. Markus Garst
Prof. Dr. Alexander Mirlin
Prof. Dr. Alexander Shnirman

Organisation: KIT Department of Physics

Part of: M-PHYS-102053 - Condensed Matter Theory I, Fundamentals and Advanced Topics

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🔗 On-Site, ❌ Cancelled

Prerequisites
none
3.41 Course: Condensed Matter Theory II: Many-Body Systems, Fundamentals [T-PHYS-104591]

**Responsible:** Prof. Dr. Markus Garst  
PD Dr. Igor Gornyi  
Prof. Dr. Alexander Mirlin  
PD Dr. Boris Narozhnyy  
Prof. Dr. Jörg Schmalian

**Organisation:** KIT Department of Mathematics  
KIT Department of Physics

**Part of:** M-PHYS-102313 - Condensed Matter Theory II: Many-Body Theory, Fundamentals

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Legend: 🖥 Online, 🇫 Blended (On-Site/Online), 🗣 On-Site, ❌ Cancelled
3.42 Course: Condensed Matter Theory II: Many-Body Systems, Fundamentals and Advanced Topics [T-PHYS-102560]

**Responsible:**
- Prof. Dr. Markus Garst
- PD Dr. Igor Gornyi
- Prof. Dr. Alexander Mirlin
- PD Dr. Boris Narozhnyy
- Prof. Dr. Jörg Schmalian

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102308 - Condensed Matter Theory II: Many-Body Theory, Fundamentals and Advanced Topics

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Legend: 🖥 Online, 🗭 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
**3.43 Course: Continuous Time Finance [T-MATH-105930]**

**Responsible:**  
Prof. Dr. Nicole Bäuerle  
Prof. Dr. Vicky Fasen-Hartmann  
Prof. Dr. Mathias Trabas  

**Organisation:**  
KIT Department of Mathematics  

**Part of:**  
M-MATH-102860 - Continuous Time Finance  

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**Competence Certificate**

oral exam of ca. 30 minutes

**Prerequisites**

none

Below you will find excerpts from events related to this course:

**Continuous Time Finance**

0159400, SS 2024, 4 SWS, Open in study portal

**Lecture (V)**

**Content**

The lecture covers central topics in continuous-time finance. The first part of the course is an introduction to stochastic analysis. First, we introduce Brownian motion and important topics in the theory of martingales. We then develop the stochastic integral and describe its importance in finance. The second part of the course focuses on the analysis of the Black-Scholes model where the asset process is modelled by a geometric Brownian motion. In this market we price and hedge options. We derive the first and second fundamental theorems of asset pricing, which describe the relationships between arbitrage freedom, equivalent martingale measures and completeness. Finally, we study portfolio optimisation problems and term structure models.

**Topics:**

- Stochastic processes
- Total variation and quadratic variation
- Ito integral
- Black-Scholes model
- Bonds, futures, term structure models
### 3.44 Course: Control Theory [T-MATH-105909]

**Responsible:** Prof. Dr. Roland Schnaubelt  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102941 - Control Theory

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**Prerequisites**

none
### Course: Convex Geometry [T-MATH-105831]

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3.46 Course: Curves on Surfaces [T-MATH-113364]

**Responsible:** Dr. Elia Fioravanti

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106632 - Curves on Surfaces

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**Competence Certificate**
oral exam (ca. 20-30 min)

**Prerequisites**
none
Course: Deep Learning and Neural Networks [T-INFO-109124]

**Responsible:** Prof. Dr. Jan Niehues  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-104460 - Deep Learning and Neural Networks

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**Exams**

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**Legend:** 🖥 Online, ık Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The course T-INFO-101383 - Neural Networks must not have been started.
3.48 Course: Differential Geometry [T-MATH-102275]

**Responsible:** Prof. Dr. Wilderich Tuschmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-101317 - Differential Geometry

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**Below you will find excerpts from events related to this course:**

**Content**

This course is an introduction to modern differential geometry. Differential geometry is the study of geometry of spaces using analytic and linear algebraic methods. After laying down the foundational definitions and basic properties of smooth manifolds, tangent vectors, and Riemannian metrics, we will develop notions of linear connections and covariant derivatives allowing us to do differential calculus on these manifolds. We will continue our journey of understanding the shape of these manifolds by developing concepts of curvature tensors, geodesics, parallel transport and Jacobi fields. We will also cover the celebrated Bonnet-Myers and Cartan-Hadamard theorems which show us that curvature conditions on a manifold can to some extent dictate the geometry and topology of the manifold.
3.49 Course: Discrete Dynamical Systems [T-MATH-110952]

**Responsible:** PD Dr. Gerd Herzog

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105432 - Discrete Dynamical Systems

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**Prerequisites**

none
3.50 Course: Discrete Time Finance [T-MATH-105839]

**Responsible:** Prof. Dr. Nicole Bäuerle
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102919 - Discrete Time Finance

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗑 On-Site, ✗ Cancelled

**Competence Certificate**

Written exam of 2h.

**Prerequisites**

none

**Recommendation**

The contents of the module „Probability theory“ are strongly recommended.
3.51 Course: Dispersive Equations [T-MATH-109001]

**Responsible:** Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-104425 - Dispersive Equations

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**Prerequisites**

none
## 3.52 Course: Dynamical Systems [T-MATH-106114]

**Responsible:** Prof. Dr. Wolfgang Reichel  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103080 - Dynamical Systems

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**Prerequisites**  
none
### 3.53 Course: Elective Module - Subject, Body, Individual: the Other Side of Sustainability - Self Assignment BeNe [T-ZAK-112349]

**Organisation:**
- Part of: *M-ZAK-106099 - Supplementary Studies on Sustainable Development*

#### Type
- Examination of another type

#### Credits
- 3

#### Grading scale
- Grade to a third

#### Version
- 1

**Competence Certificate**
Examination of another kind according to § 7 section 7 in the form of a presentation in the selected course.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**
The content of the Basics Module is helpful.
3.54 Course: Elective Module - Sustainability Assessment of Technology - Self Assignment BeNe [T-ZAK-112348]

**Organisation:**
Part of: M-ZAK-106099 - Supplementary Studies on Sustainable Development

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**Competence Certificate**
Examination of another kind according to § 7 section 7 in the form of a presentation in the selected course.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**
The content of the Basics Module is helpful.
3 COURSES  Course: Elective Module - Sustainability in Culture, Economy and Society - Self Assignment BeNe [T-ZAK-112350]

3.55 Course: Elective Module - Sustainability in Culture, Economy and Society - Self Assignment BeNe [T-ZAK-112350]

Organisation:
Part of: M-ZAK-106099 - Supplementary Studies on Sustainable Development

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**Competence Certificate**
Examination of another kind according to § 7 section 7 in the form of a presentation in the selected course.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**
The content of the Basics Module is helpful.
3.56 Course: Elective Module - Sustainable Cities and Neighbourhoods - Self Assignment BeNe [T-ZAK-112347]

**Organisation:** University

**Part of:** M-ZAK-106099 - Supplementary Studies on Sustainable Development

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**Competence Certificate**

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**Prerequisites**

Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**

This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Recommendation**

The content of the Basics Module is helpful.
3.57 Course: Electromagnetics and Numerical Calculation of Fields [T-ETIT-100640]

**Responsible:** Prof. Dr.-Ing. Thomas Zwick  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-100386 - Electromagnetics and Numerical Calculation of Fields

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**Exams**

| WT 23/24 | 7308263 | Electromagnetics and Numerical Calculation of Fields | Pauli |

Legend: 🖥 Online, 🔄 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Competence Certificate**

Success control is carried out in the form of a written test of 120 minutes.

**Prerequisites**

none

**Recommendation**

Fundamentals of electromagnetic field theory.
### 3.58 Course: Electronic Properties of Solids I, with Exercises [T-PHYS-102577]

#### Responsible:
- Prof. Dr. Matthieu Le Tacon
- Prof. Dr. Wolfgang Wernsdorfer
- Prof. Dr. Wulf Wulfhekel

#### Organisation:
KIT Department of Physics

#### Part of:
- M-PHYS-102089 - Electronic Properties of Solids I, with Exercises

#### Type
- Oral examination

#### Credits
- 10

#### Grading scale
- Grade to a third

#### Version
- 1

### Events

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗺 On-Site, ✗ Cancelled

#### Prerequisites
- none

**Responsible:** Prof. Dr. Matthieu Le Tacon  
Prof. Dr. Wolfgang Wernsdorfer  
Prof. Dr. Wulf Wulfhekel

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102090 - Electronic Properties of Solids I, without Exercises

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**Prerequisites**

none
### 3.60 Course: Electronic Properties of Solids II, with Exercises [T-PHYS-104422]

**Responsible:**
- Prof. Dr. Matthieu Le Tacon
- Dr. Johannes Rotzinger
- Prof. Dr. Alexey Ustinov
- Prof. Dr. Wolfgang Wernsdorfer

**Organisation:**
- KIT Department of Physics

**Part of:**
- M-PHYS-102108 - Electronic Properties of Solids II, with Exercises

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**Legend:**
- 🖥 Online
- 🧱 Blended (On-Site/Online)
- 🗣 On-Site
- 🗑 Cancelled

**Prerequisites**

None

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
3.61 Course: Electronic Properties of Solids II, without Exercises [T-PHYS-104423]

**Responsible:** Prof. Dr. Matthieu Le Tacon  
Dr. Johannes Rotzinger  
Prof. Dr. Alexey Ustinov  
Prof. Dr. Wolfgang Wernsdorfer

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102109 - Electronic Properties of Solids II, without Exercises

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**Events**

| ST 2024 | 4021111 | Electronic properties of solids II | 2 SWS | Lecture / 🗣 | Ustinov |

Legend: 🖥 Online, ☐ Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Prerequisites**

none
### 3.62 Course: Ergodic Theory [T-MATH-113086]

**Responsible:** Dr. Gabriele Link  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-106473 - Ergodic Theory

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**Exams**
- WT 23/24 7700114 Ergodic Theory Link
- ST 2024 7700114 Ergodic Theory Link

**Competence Certificate**  
Oral examination of ca. 20-30 minutes.

**Prerequisites**  
none

**Recommendation**  
Some basic knowledge of measure theory, topology, geometry, group theory and functional analysis is recommended.
### 3.63 Course: Evolution Equations [T-MATH-105844]

**Responsible:** Prof. Dr. Dorothee Frey  
apl. Prof. Dr. Peer Kunstmann  
Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102872 - Evolution Equations

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3.64 Course: Exponential Integrators [T-MATH-107475]

**Responsible:** Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103700 - Exponential Integrators

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**Prerequisites**  
none
3.65 Course: Extremal Graph Theory [T-MATH-105931]

**Responsible:** Prof. Dr. Maria Aksenovich

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102957 - Extremal Graph Theory

**Type**
Oral examination

**Credits**
4

**Grading scale**
Grade to a third

**Recurrence**
Irregular

**Version**
2

**Prerequisites**
none
### 3.66 Course: Extreme Value Theory [T-MATH-105908]

**Responsible:** Prof. Dr. Vicky Fasen-Hartmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102939 - Extreme Value Theory

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| Events       |          |                         |         |         |
|--------------|----------|-------------------------|---------|
| ST 2024      | 0155600  | Extremwerttheorie        | 2 SWS   | Lecture | Fasen-Hartmann |
| ST 2024      | 0155610  | Übungen zu 0155600      | 1 SWS   | Practice| Fasen-Hartmann |
### 3.67 Course: Finite Element Methods [T-MATH-105857]

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke  
Prof. Dr. Andreas Rieder  
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102891 - Finite Element Methods

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**Responsible:** Prof. Dr. Tilmann Gneiting

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102956 - Forecasting: Theory and Practice
# 3.69 Course: Formal Systems [T-INFO-101336]

**Responsible:** Prof. Dr. Bernhard Beckert  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100799 - Formal Systems

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## Events

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## Exams

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3.70 Course: Foundations of Continuum Mechanics [T-MATH-107044]

**Responsible:** Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-103527 - Foundations of Continuum Mechanics

**Type**
Oral examination

**Credits**
3

**Grading scale**
Grade to a third

**Recurrence**
Once

**Version**
1

**Prerequisites**
none
3.71 Course: Fourier Analysis and its Applications to PDEs [T-MATH-109850]

**Responsible:** TT-Prof. Dr. Xian Liao

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-104827 - Fourier Analysis and its Applications to PDEs

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**Prerequisites**

none
3.72 Course: Fractal Geometry [T-MATH-111296]

**Responsible:** PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105649 - Fractal Geometry

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**Prerequisites**

none
3.73 Course: Functional Analysis [T-MATH-102255]

**Responsible:** Prof. Dr. Dorothee Frey
PD Dr. Gerd Herzog
Prof. Dr. Dirk Hundertmark
Prof. Dr. Tobias Lamm
TT-Prof. Dr. Xian Liao
Prof. Dr. Wolfgang Reichel
Prof. Dr. Roland Schnaubelt
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-101320 - Functional Analysis

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**Exams**

| WT 23/24 | 0100047 | Functional Analysis | Lamm, Hundertmark, Kunstmann, Schnaubelt, Frey, Liao |

Legend: 🖥 Online, ☪ Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled

**Competence Certificate**
Written examination of 120 minutes.

**Prerequisites**
none
### Course: Functional Data Analysis [T-MATH-113102]

**Responsible:** Dr. rer. nat. Bruno Ebner  
PD Dr. Bernhard Klar  
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106485 - Functional Data Analysis

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**Competence Certificate**

Oral examination of ca. 25 minutes.

**Prerequisites**

none

**Recommendation**

The contents of the modules "Probability Theory" and "Mathematical Statistics" are strongly recommended.
Course: Functions of Matrices [T-MATH-105906]

**Responsible:** PD Dr. Volker Grimm

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102937 - Functions of Matrices

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**Prerequisites**
none
3.76 Course: Functions of Operators [T-MATH-105905]

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# 3.77 Course: Fuzzy Sets [T-INFO-101376]

**Responsible:** Prof. Dr.-Ing. Uwe Hanebeck  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100839 - Fuzzy Sets

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3.78 Course: Generalized Regression Models [T-MATH-105870]

**Responsible:** Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102906 - Generalized Regression Models

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3.79 Course: Geometric Analysis [T-MATH-105892]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102923 - Geometric Analysis

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<td>WT 23/24</td>
<td>7700140</td>
<td>Geometric Analysis</td>
</tr>
</tbody>
</table>

**Prerequisites**

none
Below you will find excerpts from events related to this course:

**Content**
This course will provide an introduction to geometric group theory, which studies the interactions between finitely generated groups and geometric spaces, creating connections between algebra and geometry. While a priori groups may seem like purely algebraic objects, they can naturally arise as symmetries of geometric objects. For instance, the symmetries of a regular n-gon form a group (the dihedral group \(D_n\)). In fact, every finitely generated group admits a natural action by isometries on a metric space, known as its Cayley graph. For instance the Cayley graph of the integers is the real line with vertices given by the integer points and the group action defined by translation.

Studying group actions on geometric spaces, allows us to gain insights into "the geometry of groups". Conversely, knowing that a geometric space admits an interesting group action allows us to obtain a better understanding of the space itself. Over the last decades, these interactions between group theory and geometry have led to an array of fundamental results in both areas. This course will provide an introduction to these interactions and their consequences.

In particular, we will learn about

- finitely generated groups and group presentations
- Cayley graphs and group actions
- quasi-isometries of metric spaces, quasi-isometry invariants and the Theorem of Schwarz-Milnor
- explicit examples of infinite groups and their connections to geometry

Prerequisites are:
Knowledge of the basic concepts on metric and topological spaces, as well as some familiarity with the basic concepts in group theory are recommended.
### 3.81 Course: Geometric Group Theory II [T-MATH-105875]

**Responsible:** Prof. Dr. Frank Herrlich  
Jun.-Prof. Dr. Claudio Llosa Isenrich  
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102869 - Geometric Group Theory II

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| Events | | |
|---|---|---|---|---|
| WT 23/24 | 0102900 | Geometric Group Theory II | 4 SWS | Lecture | Llosa Isenrich |
| WT 23/24 | 0102910 | Tutorial for 0102900 (Geometric Group Theory II) | 2 SWS | Practice | Llosa Isenrich |

| Exams | |
|---|---|---|
| WT 23/24 | 7700133 | Geometric Group Theory II | | Llosa Isenrich |
3.82 Course: Geometric Numerical Integration [T-MATH-105919]

**Responsible:** Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102921 - Geometric Numerical Integration

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**Prerequisites**
none
3.83 Course: Geometric Variational Problems [T-MATH-113418]

**Responsible:** Prof. Dr. Tobias Lamm

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106667 - Geometric Variational Problems

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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
one
T 3.84 Course: Geometry of Schemes [T-MATH-105841]

Responsible: Prof. Dr. Frank Herrlich
PD Dr. Stefan Kühnlein

Organisation: KIT Department of Mathematics

Part of: M-MATH-102866 - Geometry of Schemes

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Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
3.85 Course: Global Differential Geometry [T-MATH-105885]

**Responsible:** Prof. Dr. Wilderich Tuschmann

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102912 - Global Differential Geometry

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**Prerequisites**
none
3.86 Course: Graph Theory [T-MATH-102273]

- **Responsible:** Prof. Dr. Maria Aksenovich
- **Organisation:** KIT Department of Mathematics
- **Part of:** M-MATH-101336 - Graph Theory

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**Exams**

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**Prerequisites**

None

Below you will find excerpts from events related to this course:

**Graph Theory**

0104500, WS 23/24, 4 SWS, Language: English, [Open in study portal](#)

**Content**

Graphs are structures in discrete mathematics that in particular model various networks. The course starts with basic concepts in graph theory such as trees, cycles, matchings, factors, connectivity, and their interconnections. Further topics include properties of graphs with forbidden subgraphs, planar graphs, graph colorings, random graphs, Ramsey theory, and graph minors. Not only classical, but very recent results in the field will be discussed. The class is oriented towards problem solving. Particular attention to proof writing techniques will be paid in the problem class. The final grade will be based on the written exam. Bonus points will be given for weekly or biweekly homework assignments.
3.87 Course: Group Actions in Riemannian Geometry [T-MATH-105925]

**Responsible:** Prof. Dr. Wilderich Tuschmann

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102954 - Group Actions in Riemannian Geometry

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**Prerequisites**
none
### 3.88 Course: Harmonic Analysis [T-MATH-111289]

**Responsible:** Prof. Dr. Dorothee Frey  
apl. Prof. Dr. Peer Kunstmann  
Prof. Dr. Roland Schnaubelt  
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105324 - Harmonic Analysis

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**Exams**

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<th>Harmonic Analysis</th>
<th>Frey, Tolksdorf</th>
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3.89 Course: Harmonic Analysis 2 [T-MATH-113103]

**Responsible:** Prof. Dr. Dorothee Frey
ap. Prof. Dr. Peer Kunstmann
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106486 - Harmonic Analysis 2

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**Type**  
Oral examination

**Credits**  
8

**Grading scale**  
Grade to a third

**Version**  
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**Competence Certificate**
oral examination of ca. 30 minutes.

**Prerequisites**
none

**Recommendation**
The following modules are strongly recommended: "Harmonic Analysis", "Functional Analysis".
### 3.90 Course: Heat Transfer II [T-CIWVT-106067]

**Responsible:** Prof. Dr.-Ing. Thomas Wetzel  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103051 - Heat Transfer II

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#### Events

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#### Exam

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<td>Heat Transfer II</td>
<td>Wetzel</td>
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**Legend:** 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
3.91 Course: High Temperature Process Engineering [T-CIWVT-106109]

**Responsible:** Prof. Dr.-Ing. Dieter Stapf

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** M-CIWVT-103075 - High Temperature Process Engineering

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**Events**

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<td>High Temperature Process Engineering - Exercises</td>
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**Exams**

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<tr>
<td>ST 2024</td>
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<td>High Temperature Process Engineering</td>
<td>Stapf</td>
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**Prerequisites**

None

Legend: 🖥 Online, 🤍 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
3.92 Course: Homotopy Theory [T-MATH-105933]

**Responsible:** Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102959 - Homotopy Theory

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<td>Grade to a third</td>
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3.93 Course: In-depth Module - Doing Culture - Self Assignment BAK [T-ZAK-112655]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
Part of: M-ZAK-106235 - Supplementary Studies on Culture and Society

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<td>Grade to a third</td>
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**Competence Certificate**
At least two presentations must be given: An examination of another kind according to § 5 section 3 (3) in the form of a presentation in one of the chosen courses (3 ECT).

In a third seminar, either (a) a presentation is held (preliminary study achievement) which remains not graded and a topic-related term paper is submitted or (b) a written exam is taken.

The three courses can be selected individually from the 5 thematic blocks or – in exceptional cases and according to the agreement with the responsible lecturer – all three courses can be selected from one block in the sense of a specialization.

In addition, an oral examination is taken, which relates to the content of two of the chosen three courses.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Annotation**
The content of the Basic Module is helpful.
3.94 Course: In-depth Module - Global Cultures - Self Assignment BAK [T-ZAK-112658]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
Part of: M-ZAK-106235 - Supplementary Studies on Culture and Society

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**Competence Certificate**
At least two presentations must be given: An examination of another kind according to § 5 section 3 (3) in the form of a presentation in one of the chosen courses (3 ECT).
In a third seminar, either (a) a presentation is held (preliminary study achievement) which remains not graded and a topic-related term paper is submitted or (b) a written exam is taken.
The three courses can be selected individually from the 5 thematic blocks or – in exceptional cases and according to the agreement with the responsible lecturer – all three courses can be selected from one block in the sense of a specialization.
In addition, an oral examination is taken, which relates to the content of two of the chosen three courses.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Annotation**
The content of the Basic Modul is helpful.
3.95 Course: In-depth Module - Media & Aesthetics - Self Assignment BAK [T-ZAK-112656]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
Part of: M-ZAK-106235 - Supplementary Studies on Culture and Society

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**Competence Certificate**
At least two presentations must be given: An examination of another kind according to § 5 section 3 (3) in the form of a presentation in one of the chosen courses (3 ECT).
In a third seminar, either (a) a presentation is held (preliminary study achievement) which remains not graded and a topic-related term paper is submitted or (b) a written exam is taken.
The three courses can be selected individually from the 5 thematic blocks or – in exceptional cases and according to the agreement with the responsible lecturer – all three courses can be selected from one block in the sense of a specialization. In addition, an oral examination is taken, which relates to the content of two of the chosen three courses.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Annotation**
The content of the Basic Modul is helpful.
3.96 Course: In-depth Module - Spheres of Life - Self Assignment BAK [T-ZAK-112657]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
- **Part of:** M-ZAK-106235 - Supplementary Studies on Culture and Society

**Type**
- Examination of another type

**Credits**
- 3

**Grading scale**
- Grade to a third

**Version**
- 1

**Competence Certificate**
At least two presentations must be given: An examination of another kind according to § 5 section 3 (3) in the form of a presentation in one of the chosen courses (3 ECT).
In a third seminar, either (a) a presentation is held (preliminary study achievement) which remains not graded and a topic-related term paper is submitted or (b) a written exam is taken.
The three courses can be selected individually from the 5 thematic blocks or – in exceptional cases and according to the agreement with the responsible lecturer – all three courses can be selected from one block in the sense of a specialization.
In addition, an oral examination is taken, which relates to the content of two of the chosen three courses.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Annotation**
The content of the Basic Module is helpful.
### 3.97 Course: In-depth Module - Technology & Responsibility - Self Assignment BAK [T-ZAK-112654]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
- **Part of:** M-ZAK-106235 - Supplementary Studies on Culture and Society

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**Competence Certificate**
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In a third seminar, either (a) a presentation is held (preliminary study achievement) which remains not graded and a topic-related term paper is submitted or (b) a written exam is taken.
The three courses can be selected individually from the 5 thematic blocks or – in exceptional cases and according to the agreement with the responsible lecturer – all three courses can be selected from one block in the sense of a specialization.
In addition, an oral examination is taken, which relates to the content of two of the chosen three courses.

**Prerequisites**
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.

**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:
- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

**Annotation**
The content of the Basic Modul is helpful.
3.98 Course: Infinite dimensional dynamical systems [T-MATH-107070]

**Responsible:** Prof. Dr. Jens Rottmann-Matthes

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-103544 - Infinite dimensional dynamical systems

**Type:** Oral examination

**Credits:** 4

**Grading scale:** Grade to a third

**Recurrence:** Irregular

**Version:** 1

**Prerequisites**

none

**Responsible:** Prof. Dr. Jörn Müller-Quade

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-106015 - Information Security

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**Events**

| ST 2024 | 2400199 | Informationssicherheit | 3 SWS | Lecture / Practice (Müller-Quade, Strufe, Hartenstein, Wressnegger) |

**Exams**

| WT 23/24 | 7500003 | Information Security | Wressnegger, Müller-Quade, Strufe |

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The course T-INFO-101371 - Security must not have been started.
### 3.100 Course: Integral Equations [T-MATH-105834]

**Responsible:**  
PD Dr. Tilo Arens  
Prof. Dr. Roland Griesmaier  
PD Dr. Frank Hettlich

**Organisation:**  
KIT Department of Mathematics

**Part of:**  
M-MATH-102874 - Integral Equations

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**Events**

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3.101 Course: Internet Seminar for Evolution Equations [T-MATH-105890]

**Responsible:**  
Prof. Dr. Dorothee Frey  
apl. Prof. Dr. Peer Kunstmann  
Prof. Dr. Roland Schnaubelt  
Dr. rer. nat. Patrick Tolksdorf

**Organisation:**  
KIT Department of Mathematics

**Part of:**  
M-MATH-102918 - Internet Seminar for Evolution Equations

**Type**  
Written examination

**Credits**  
8

**Grading scale**  
Grade to a third

**Version**  
1

**Events**

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<th>Internetseminar für Evolutionsgleichungen</th>
<th>2 SWS</th>
<th>Lecture / 🗣</th>
<th>Schnaubelt, Kunstmann, Frey, Tolksdorf</th>
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**Exams**

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<th>Internet Seminar for Evolution Equations</th>
<th>Tolksdorf, Frey, Kunstmann, Schnaubelt</th>
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Legend: 🖥 Online, 🍣 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Competence Certificate**

oral examination of ca. 30 minutes

**Prerequisites**

none
3.102 Course: Internship [T-MATH-105888]

**Responsible:** Prof. Dr. Willy Dörfler
PD Dr. Markus Neher

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102861 - Internship

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### 3.103 Course: Introduction into Particulate Flows [T-MATH-105911]

**Responsible:** Prof. Dr. Willy Dörfler

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102943 - Introduction into Particulate Flows

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**Prerequisites**

none
3.104 Course: Introduction to Aperiodic Order [T-MATH-110811]

**Responsible:** Prof. Dr. Tobias Hartnick

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105331 - Introduction to Aperiodic Order

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**Prerequisites**

none
### 3.105 Course: Introduction to Artificial Intelligence [T-INFO-112194]

**Responsible:** TT-Prof. Dr. Pascal Friederich  
Prof. Dr. Gerhard Neumann

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-106014 - Introduction to Artificial Intelligence

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<td>Lecture / Practice</td>
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**Exams**

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**Legend:**  🖥 Online,  🧩 Blended (On-Site/Online),  🗣 On-Site,  ✗ Cancelled

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The course T-INFO-101356 - Cognitive Systems must not have been started.
3.106 Course: Introduction to Convex Integration [T-MATH-112119]

**Responsible:** Dr. Christian Zillinger  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105964 - Introduction to Convex Integration

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<td>Zillinger</td>
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**Exams**

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<th>Recurrence</th>
<th>Expansion</th>
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**Competence Certificate**
oral examination of approx. 30 minutes

**Prerequisites**
none

**Recommendation**
The courses "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.
### 3.107 Course: Introduction to Cosmology [T-PHYS-102384]

**Responsible:** Prof. Dr. Guido Drexlin  
**Organisation:** KIT Department of Physics  
**Part of:** M-PHYS-102175 - Introduction to Cosmology

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#### Events

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<td>Practice / 🗣️</td>
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**Legend:** 🖥 Online, 🤖 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled

Below you will find excerpts from events related to this course:

#### Introduction to Cosmology

**4022021, WS 23/24, 2 SWS, Language: English,** [Open in study portal](#)

**Lecture (V)**  
On-Site

**Content**

An Introduction to cosmology from the Big Bang to the present universe
3.108 Course: Introduction to Dynamical Systems [T-MATH-113263]

**Responsible:**
- Dr. Björn de Rijk
- Prof. Dr. Wolfgang Reichel

**Organisation:**
- KIT Department of Mathematics

**Part of:**
- M-MATH-106591 - Introduction to Dynamical Systems

**Type**
- Oral examination

**Credits**
- 6

**Grading scale**
- Grade to a third

**Recurrence**
- Irregular

**Version**
- 1

<table>
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<td>oral exam</td>
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**Competence Certificate**

oral exam of ca. 30 min

**Prerequisites**

none
### 3.109 Course: Introduction to Fluid Dynamics [T-MATH-111297]

| **Responsible:** | Prof. Dr. Wolfgang Reichel |
| **Organisation:** | KIT Department of Mathematics |
| **Part of:** | M-MATH-105650 - Introduction to Fluid Dynamics |

| **Type** | Oral examination |
| **Credits** | 3 |
| **Grading scale** | Grade to a third |
| **Recurrence** | Irregular |
| **Version** | 1 |

**Prerequisites**
none
### 3.110 Course: Introduction to Fluid Mechanics [T-MATH-112927]

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<th>Responsible:</th>
<th>TT-Prof. Dr. Xian Liao</th>
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<tr>
<td>Part of:</td>
<td>M-MATH-106401 - Introduction to Fluid Mechanics</td>
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<td>1 terms</td>
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**Competence Certificate**
The module examination takes the form of an oral examination of approx. 25 minutes.

**Prerequisites**
none

**Recommendation**
The module *Functional Analysis* is strongly recommended.
### 3.111 Course: Introduction to Geometric Measure Theory [T-MATH-105918]

**Responsible:** PD Dr. Steffen Winter  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102949 - Introduction to Geometric Measure Theory

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**Prerequisites**  
none
3.112 Course: Introduction to Homogeneous Dynamics [T-MATH-110323]

**Responsible:** Prof. Dr. Tobias Hartnick

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105101 - Introduction to Homogeneous Dynamics

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**Prerequisites**
none
3.113 Course: Introduction to Kinetic Equations [T-MATH-111721]

**Responsible:** Dr. Christian Zillinger

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105837 - Introduction to Kinetic Equations

<table>
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<th>Recurrence</th>
<th>Expansion</th>
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<td>Irregular</td>
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**Competence Certificate**
oral examination of circa 30 minutes

**Prerequisites**
none

**Recommendation**
The course "Classical Methods for Partial Differential Equations" should be studied beforehand.
### 3.114 Course: Introduction to Kinetic Theory [T-MATH-108013]

**Responsible:** Prof. Dr. Martin Frank  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103919 - Introduction to Kinetic Theory

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<th>Recurrence</th>
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<td>Introduction to Kinetic Theory</td>
<td>2 SWS</td>
<td>Lecture / Online, Frank</td>
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**Legend:** 🖥 Online, ☑ Blended (On-Site/Online), 📅 On-Site, ☑ Cancelled

**Prerequisites**
none

**Below you will find excerpts from events related to this course:**

### Introduction to Kinetic Theory

**0155450, WS 23/24, 2 SWS, Language: English, Open in study portal**

**Lecture (V)**

**Blended (On-Site/Online)**

**Content**

Kinetic descriptions play an important role in a variety of physical, biological, and even social applications, for instance, in the description of gases, radiations, bacteria or financial markets. Typically, these systems are described locally not by a finite set of variables but instead by a probability density describing the distribution of a microscopic state. Its evolution is typically given by an integro-differential equation. Unfortunately, the large phase space associated with the kinetic description has made simulations impractical in most settings in the past. However, recent advances in computer resources, reduced-order modeling and numerical algorithms are making accurate approximations of kinetic models more tractable, and this trend is expected to continue in the future. On the theoretical mathematical side, two rather recent Fields medals (Pierre-Louis Lions 1994, Cédric Villani 2010) also indicate the continuing interest in this field, which was already the subject of Hilbert’s sixth out of the 23 problems presented at the World Congress of Mathematicians in 1900.

This course gives an introduction to kinetic theory. Our purpose is to discuss the mathematical passage from a microscopic description of a system of particles, via a probabilistic description to a macroscopic view. This is done in a complete way for the linear case of particles that are interacting with a background medium. The nonlinear case of pairwise interacting particles is treated on a more phenomenological level.

An extremely broad range of mathematical techniques is used in this course. Besides mathematical modeling, we make use of statistics and probabilistic theory, ordinary differential equations, hyperbolic partial differential equations, integral equations (and thus functional analysis) and infinite-dimensional optimization. Among the astonishing discoveries of kinetic theory are the statistical interpretation of the Second Law of Thermodynamics, induced by the Boltzmann-Grad limit, and the result that the macroscopic equations describing fluid motion (namely the Euler and Navier-Stokes equations) can be inferred from abstract geometrical properties of integral scattering operators.

**Organizational issues**

The course will be offered in flipped classroom format. Flipped classroom means that the lectures will be made available as videos. We will regularly meet for tutorials and discussion sessions.
### 3.115 Course: Introduction to Microlocal Analysis [T-MATH-111722]

**Responsible:** TT-Prof. Dr. Xian Liao  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105838 - Introduction to Microlocal Analysis

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**Competence Certificate**  
oral examination of circa 30 minutes

**Prerequisites**  
none

**Recommendation**  
The courses "Classical Methods for Partial Differential Equations" and "Functional Analysis" should be studied beforehand.
### 3.116 Course: Introduction to Python [T-MATH-106119]

**Responsible:** Dr. Daniel Weiß  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102994 - Key Competences

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<th>Lecture</th>
<th>Weiß</th>
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</table>

Techno-Mathematics Master 2016 (Master of Science (M.Sc.))  
Module Handbook as of 05/03/2024
Course: Introduction to Python - Programming Project [T-MATH-111851]

3.117 Course: Introduction to Python - Programming Project [T-MATH-111851]

**Responsible:** Dr. Daniel Weiß

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102994 - Key Competences

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Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024

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3.118 Course: Introduction to Scientific Computing [T-MATH-105837]

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke  
Prof. Dr. Andreas Rieder  
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102889 - Introduction to Scientific Computing

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</table>
3.119 Course: Introduction to Stochastic Differential Equations [T-MATH-112234]

**Responsible:** Josef Janák
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106045 - Introduction to Stochastic Differential Equations

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**Competence Certificate**

The module will be completed with an oral exam (approx. 30 min).

**Prerequisites**

none

**Recommendation**

The contents of the module "Probability Theory" are strongly recommended. The module "Continuous Time Finance" is recommended.
### 3.120 Course: Inverse Problems [T-MATH-105835]

| Responsible: | PD Dr. Tilo Arens  
|             | Prof. Dr. Roland Griesmaier  
|             | PD Dr. Frank Hettlich  
|             | Prof. Dr. Andreas Rieder  
| Organisation: | KIT Department of Mathematics  
| Part of: | M-MATH-102890 - Inverse Problems  

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#### Events

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<th>4 SWS</th>
<th>Lecture / 🗣</th>
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#### Exams

| WT 23/24 | 7700131 | Inverse Problems | Griesmaier |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
### 3.121 Course: IT Security [T-INFO-112818]

**Responsible:** Prof. Dr. Hannes Hartenstein  
Prof. Dr. Jörn Müller-Quade  
Prof. Dr. Thorsten Strufe  
TT-Prof. Dr. Christian Wressnegger

**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-106315 - IT Security

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<td>Each winter term</td>
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**Events**

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<tr>
<th>Event</th>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Lecture / Practice</th>
<th>Tutors</th>
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<td>IT Security</td>
<td>4 SWS</td>
<td>Lecture / Practice</td>
<td>Müller-Quade, Strufe, Wressnegger, Hartenstein</td>
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**Exams**

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</table>

**Legend:** 🖥 Online, ⚽ Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Competence Certificate**
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 90 minutes.

**Prerequisites**
None.

**Recommendation**
Students should be familiar with the content of the compulsory lecture "Informationssicherheit".
### 3.122 Course: Key Moments in Geometry [T-MATH-108401]

**Responsible:** Prof. Dr. Wilderich Tuschmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-104057 - Key Moments in Geometry

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**Prerequisites**  
none
3.123 Course: L2-Invariants [T-MATH-105924]

**Responsible:** Dr. Holger Kammeyer  
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102952 - L2-Invariants

**Type**  
Oral examination

**Credits**  
5

**Grading scale**  
Grade to a third

**Version**  
1

**Prerequisites**  
none
3.124 Course: Lie Groups and Lie Algebras [T-MATH-108799]

**Responsible:** Prof. Dr. Tobias Hartnick

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-104261 - Lie Groups and Lie Algebras

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3.125 Course: Lie-Algebras (Linear Algebra 3) [T-MATH-111723]

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105839 - Lie-Algebras (Linear Algebra 3)

<table>
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</table>

**Prerequisites**

none
Below you will find excerpts from events related to this course:

**Content**

This module provides a systematic introduction into the topic of localization methods. In order to facilitate understanding, the module is divided into four main topics. Dead reckoning treats the instantaneous determination of a vehicle's position based on dynamic parameters like velocity or steering angle. Localization with the help of measurements of known landmarks is part of static localization. In addition to the closed-form solutions for particular measurements (distances and angles), the least squares method for fusion arbitrary measurements is also introduced. Dynamic localization treats the combination of dead reckoning and static localization. The central part of the lecture is the derivation of the Kalman filter, which has been successfully applied in several practical applications. Finally, simultaneous localization and mapping (SLAM) is introduced, which allows localization in case of (partly) unknown landmark positions.

**Organizational issues**

Prüfungsterminvorschläge und das Verfahren dazu sind auf der Webseite der Vorlesung zu finden.

**Literature**

Grundlegende Kenntnisse der linearen Algebra und Stochastik sind hilfreich.
3.127 Course: Markov Decision Processes [T-MATH-105921]

Responsible: Prof. Dr. Nicole Bäuerle
Organisation: KIT Department of Mathematics
Part of: M-MATH-102907 - Markov Decision Processes

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Prerequisites
none
3.128 Course: Master's Thesis [T-MATH-105878]

**Responsible:** PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102917 - Master's Thesis

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**Final Thesis**

This course represents a final thesis. The following periods have been supplied:

- **Submission deadline**: 6 months
- **Maximum extension period**: 3 months
- **Correction period**: 8 weeks
3.129 Course: Mathematical Methods in Signal and Image Processing [T-MATH-105862]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102897 - Mathematical Methods in Signal and Image Processing

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**Prerequisites**

none
3.130 Course: Mathematical Methods of Imaging [T-MATH-106488]

**Responsible:** Prof. Dr. Andreas Rieder

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-103260 - Mathematical Methods of Imaging

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<th>Lecture</th>
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<td>Übungen zu 0102900 (mathematische Methoden der Bildgebung)</td>
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**Prerequisites**

None
3.131 Course: Mathematical Modelling and Simulation in Practise [T-MATH-105889]

**Responsible:** PD Dr. Gudrun Thäter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102929 - Mathematical Modelling and Simulation in Practise

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**Exams**

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<tbody>
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<td>Thäter</td>
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Below you will find excerpts from events related to this course:

**Mathematical Modelling and Simulation**

0109400, WS 23/24, 2 SWS, Language: English, Open in study portal
3.132 Course: Mathematical Statistics [T-MATH-105872]

**Responsible:** Dr. rer. nat. Bruno Ebner  
Prof. Dr. Vicky Fasen-Hartmann  
PD Dr. Bernhard Klar  
Prof. Dr. Mathias Trabs

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102909 - Mathematical Statistics

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**Exams**

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**Prerequisites**

none
3.133 Course: Mathematical Topics in Kinetic Theory [T-MATH-108403]

**Responsible:** Prof. Dr. Dirk Hundertmark

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-104059 - Mathematical Topics in Kinetic Theory

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**Prerequisites**

none
3.134 Course: Maxwell's Equations [T-MATH-105856]

**Responsible:** PD Dr. Tilo Arens
Prof. Dr. Roland Griesmaier
PD Dr. Frank Hettlich

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102885 - Maxwell's Equations

<table>
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<tbody>
<tr>
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### 3.135 Course: Medical Imaging Technology I [T-ETIT-113048]

**Responsible:** Prof. Dr.-Ing. Maria Francesca Spadea  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-106449 - Medical Imaging Technology I

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**Exams**

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<td>Spadea</td>
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**Competence Certificate**

The examination takes place in form of a written examination lasting 60 minutes. The course grade is the grade of the written exam.

**Prerequisites**

none
3.136 Course: Medical Imaging Technology II [T-ETIT-113421]

Responsible: Prof. Dr.-Ing. Maria Francesca Spadea
Organisation: KIT Department of Electrical Engineering and Information Technology
Part of: M-ETIT-106670 - Medical Imaging Technology II

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Legend: 🖥 Online, ☢️ Blended (On-Site/Online), 🗣 On-Site, ☒️ Cancelled

Competence Certificate
The examination takes place in form of a written examination lasting 60 minutes. The course grade is the grade of the written exam.

Prerequisites
none
### 3.137 Course: Methods of Signal Processing [T-ETIT-100694]

**Responsible:** Prof. Dr.-Ing. Michael Heizmann  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-100540 - Methods of Signal Processing

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**Exams**

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**Events**

**Prerequisites**

none
3.138 Course: Metric Geometry [T-MATH-111933]

**Responsible:** Prof. Dr. Alexander Lytchak  
Dr. Artem Nepechiy

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105931 - Metric Geometry

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**Competence Certificate**
oral examination of circa 20 minutes

**Prerequisites**
none
3.139 Course: Minimal Surfaces [T-MATH-113417]

**Responsible:** Dr. Peter Lewintan

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106666 - Minimal Surfaces

<table>
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**Prerequisites**
None
### 3.140 Course: Modelling and Simulation of Lithium-Ion Batteries [T-MATH-113382]

**Responsible:** Prof. Dr. Willy Dörfler  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-106640 - Modelling and Simulation of Lithium-Ion Batteries

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**Competence Certificate**  
oral exam (ca. 20 min)

**Prerequisites**  
None
### 3.141 Course: Models of Mathematical Physics [T-MATH-105846]

**Responsible:** Prof. Dr. Dirk Hundertmark  
Prof. Dr. Michael Plum  
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102875 - Models of Mathematical Physics

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3.142 Course: Modern Experimental Physics I, Atoms, Nuclei and Molecules [T-PHYS-112846]

Responsibility: Studiendekan Physik
Organisation: KIT Department of Physics
Part of: M-PHYS-106331 - Modern Experimental Physics I, Atoms, Nuclei and Molecules

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Events

| ST 2024 | 4010041 | Modern Experimental Physics I, Atoms, Nuclei and Molecules | 4 SWS | Lecture / 🗣️ | Müller |
| ST 2024 | 4010042 | Übungen zu Moderne Experimentalphysik I | 2 SWS | Practice / 🗣️ | Müller, Hinz |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled

Compeence Certificate
Oral exam, approx. 45 min

Prerequisites
successful completion of the exercises

Modeled Conditions
The following conditions have to be fulfilled:

1. The following conditions have to be fulfilled:
Course: Modern Experimental Physics II, Structure of Matter [T-PHYS-112847]

 Responsible: Studiendekan Physik
 Organisation: KIT Department of Physics
 Part of: M-PHYS-106332 - Modern Experimental Physics II, Structure of Matter

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Events

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Legend: 🖥 Online, ☑ Blended (On-Site/Online), 🔒 On-Site, ☓ Cancelled

Competence Certificate
Oral exam, approx. 45 min

Prerequisites
successful completion of the exercises

Modeled Conditions
The following conditions have to be fulfilled:

1. The following conditions have to be fulfilled:
3.144 Course: Modular Forms [T-MATH-105843]

**Responsible:** PD Dr. Stefan Kühnlein  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102868 - Modular Forms

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</table>
3.145 Course: Monotonicity Methods in Analysis [T-MATH-105877]

**Responsible:** PD Dr. Gerd Herzog

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102887 - Monotonicity Methods in Analysis

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3.146 Course: Multigrid and Domain Decomposition Methods [T-MATH-105863]

**Responsible:** Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102898 - Multigrid and Domain Decomposition Methods

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**Competence Certificate**
Mündliche Prüfung im Umfang von ca. 20 Minuten.

**Prerequisites**
none
3.147 Course: Neural Networks [T-INFO-101383]

**Responsible:** Prof. Dr. Alexander Waibel  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100846 - Neural Networks

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**Events**

| ST 2024 | 2400024 | Deep Learning and Neural Networks | 4 SWS | Lecture / Niehues, Waibel |

**Exams**

| WT 23/24 | 7500259 | Deep Learning and Neural Networks | Waibel |
| ST 2024 | 7500044 | Deep Learning and Neural Networks | Niehues, Waibel |

Legend: 🖥 Online, ☐ Blended (On-Site/Online), ☑ On-Site, ✗ Cancelled

**Modeled Conditions**
The following conditions have to be fulfilled:

1. The course T-INFO-109124 - Deep Learning and Neural Networks must not have been started.
### 3.148 Course: Nonlinear Analysis [T-MATH-107065]

**Responsible:** Prof. Dr. Tobias Lamm  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103539 - Nonlinear Analysis

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**Prerequisites**  
none
3.149 Course: Nonlinear Control Systems [T-ETIT-100980]

**Responsible:** Dr.-Ing. Mathias Kluwe

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-100371 - Nonlinear Control Systems

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🔴 On-Site, ✗ Cancelled

**Prerequisites**

none
Below you will find excerpts from events related to this course:

**V Nonlinear Evolution Equations**
0156500, SS 2024, 4 SWS, Open in study portal

**Content**
Evolution equations describe the change in time of dynamical systems via an ordinary differential equation in a Banach or Hilbert space. In this lecture we study nonlinear and autonomous (time invariant) problems, whose main part is given by a generator of a linear, strongly continuous operator semigroup. In particular, we treat reaction diffusion systems and semilinear wave and Schrödinger equations. Typical topics are existence and uniqueness, continuous dependence on data, blow-up versus global-in-time existence, regularity, or the longtime behavior near equilibria. Many of the results and methods are inspired by the theory of ordinary differential equations (Analysis 4), though the presence of unbounded operators in Banach spaces leads to many new and deep difficulties and phenomena. Our approach essentially relies on a functional analytic way of thinking.

The moduls functional analysis and evolution equations are strongly recommended. The necessary contents of the latter lecture will be briefly recalled though.
3.151 Course: Nonlinear Functional Analysis [T-MATH-105876]

**Responsible:** PD Dr. Gerd Herzog

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102886 - Nonlinear Functional Analysis

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Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
3.152 Course: Nonlinear Maxwell Equations [T-MATH-110283]

**Responsible:** Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105066 - Nonlinear Maxwell Equations

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**Prerequisites**

none
3.153 Course: Nonlinear Wave Equations [T-MATH-110806]

**Responsible:** Prof. Dr. Wolfgang Reichel  
Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics  

**Part of:** M-MATH-105326 - Nonlinear Wave Equations

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**Prerequisites**
none
### 3.154 Course: Nonparametric Statistics [T-MATH-105873]

**Responsible:**  
Dr. rer. nat. Bruno Ebner  
Prof. Dr. Vicky Fasen-Hartmann  
PD Dr. Bernhard Klar  
Prof. Dr. Mathias Trabs  

**Organisation:**  
KIT Department of Mathematics  

**Part of:**  
M-MATH-102910 - Nonparametric Statistics

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**Exams**

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oral exam of ca. 20 minutes
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**3.155 Course: Numerical Analysis of Helmholtz Problems [T-MATH-111514]**

**Responsible:** TT-Prof. Dr. Barbara Verfürth

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105764 - Numerical Analysis of Helmholtz Problems
Course: Numerical Analysis of Neural Networks [T-MATH-113470]

**Responsible:** TT-Prof. Dr. Roland Maier

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106695 - Numerical Analysis of Neural Networks

**Type**
- Oral examination

**Credits**
- 6

**Grading scale**
- Grade to a third

**Version**
- 1

**Competence Certificate**
oral exam of ca. 30 minutes

**Prerequisites**
none
3.157 Course: Numerical Complex Analysis [T-MATH-112280]

**Responsible:** Prof. Dr. Marlis Hochbruck  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-106063 - Numerical Complex Analysis

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**Competence Certificate**
oral exam of ca. 20 minutes

**Prerequisites**
none

**Recommendation**
Some basic knowledge of Complex Analysis is strongly recommended.
### 3.158 Course: Numerical Linear Algebra for Scientific High Performance Computing [T-MATH-107497]

**Responsible:** Prof. Dr. Hartwig Anzt  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-103709 - Numerical Linear Algebra for Scientific High Performance Computing

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**Prerequisites**

none
### Course: Numerical Linear Algebra in Image Processing [T-MATH-108402]

**Responsible:** PD Dr. Volker Grimm  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-104058 - Numerical Linear Algebra in Image Processing

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**Prerequisites**
none

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke  
Prof. Dr. Andreas Rieder  
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102888 - Numerical Methods for Differential Equations

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**Exams**

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Legend: 🖥 Online, 💻 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled
3.161 Course: Numerical Methods for Hyperbolic Equations [T-MATH-105900]

**Responsible:** Prof. Dr. Willy Dörfler

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102915 - Numerical Methods for Hyperbolic Equations

**Type**  
Oral examination

**Credits**  
6

**Grading scale**  
Grade to a third

**Version**  
1

**Prerequisites**  
none
### 3.162 Course: Numerical Methods for Integral Equations [T-MATH-105901]

**Responsible:** PD Dr. Tilo Arens  
PD Dr. Frank Hettlich  

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102930 - Numerical Methods for Integral Equations

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Techno-Mathematics Master 2016 (Master of Science (M.Sc.))  
Module Handbook as of 05/03/2024
### 3.163 Course: Numerical Methods for Maxwell's Equations [T-MATH-105920]

**Responsible:** Prof. Dr. Marlis Hochbruck
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102931 - Numerical Methods for Maxwell's Equations

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3.164 Course: Numerical Methods for Oscillatory Differential Equations [T-MATH-113437]

Responsibility: Prof. Dr. Tobias Jahnke
Organisation: KIT Department of Mathematics
Part of: M-MATH-106682 - Numerical Methods for Oscillatory Differential Equations

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Competence Certificate
oral exam of ca. 30 minutes

Prerequisites
none
### 3.165 Course: Numerical Methods for Time-Dependent Partial Differential Equations [T-MATH-105899]

**Responsible:** Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke

**Organisation:** KIT Department of Mathematics

**Part of:**  
M-MATH-102928 - Numerical Methods for Time-Dependent Partial Differential Equations

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### 3.166 Course: Numerical Methods in Computational Electrodynamics [T-MATH-105860]

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke  
Prof. Dr. Andreas Rieder  
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102894 - Numerical Methods in Computational Electrodynamics

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**Prerequisites**
none
3.167 Course: Numerical Methods in Fluid Mechanics [T-MATH-105902]

**Responsible:** Prof. Dr. Willy Dörfler  
PD Dr. Gudrun Thäter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102932 - Numerical Methods in Fluid Mechanics

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**Events**

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Below you will find excerpts from events related to this course:

**Numerical Methods in Fluidmechanics**

**Content**

Starting from basics we develop the continuum mechanical model that lead to the fundamental equations for incompressible flows. We will study in more detail potential flows, Stokes flows (on bounded or exterior domains) and (non-turbulent) Navier-Stokes flows. We will sketch existence theory and show how to get numerical solutions with the finite element method, including stability and error estimates.
### 3.168 Course: Numerical Methods in Mathematical Finance [T-MATH-105865]

**Responsible:** Prof. Dr. Tobias Jahnke  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102901 - Numerical Methods in Mathematical Finance

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<td>Lecture</td>
<td>Jahnke</td>
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<td>WT 23/24 0107900</td>
<td>Tutorial for 0107800 (numerical methods for mathematical finance)</td>
<td>2 SWS</td>
<td>Practice</td>
<td>Jahnke, Kirn</td>
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**Competence Certificate**  
oral exam of ca. 30 minutes

**Prerequisites**  
none
### 3.169 Course: Numerical Optimisation Methods [T-MATH-105858]

**Responsible:** Prof. Dr. Willy Dörfler  
Prof. Dr. Marlis Hochbruck  
Prof. Dr. Tobias Jahnke  
Prof. Dr. Andreas Rieder  
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102892 - Numerical Optimisation Methods

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Exams: 7700126 Numerical Optimisation Methods
### 3.170 Course: Numerical Simulation in Molecular Dynamics [T-MATH-110807]

**Responsible:** PD Dr. Volker Grimm  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105327 - Numerical Simulation in Molecular Dynamics

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<td>8</td>
<td>Grade to a third</td>
<td>Irregular</td>
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**Prerequisites**

none
### 3.171 Course: Optical Waveguides and Fibers [T-ETIT-101945]

**Responsible:** Prof. Dr.-Ing. Christian Koos  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-100506 - Optical Waveguides and Fibers

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<td>ST 2024</td>
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Legend: 🕵️ Online, 🌋 Blended (On-Site/Online), 👤 On-Site, ✗ Cancelled

### Prerequisites
none
Course: Optimal Control and Estimation [T-ETIT-104594]

**Responsible:** Prof. Dr.-Ing. Sören Hohmann

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-102310 - Optimal Control and Estimation

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**Events**

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<td>Optimale Regelung und Schätzung</td>
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**Exams**

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<td>Kluwe</td>
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**Legend:** 🖥 Online, ☢ Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Prerequisites**

none
### 3.173 Course: Optimisation and Optimal Control for Differential Equations [T-MATH-105864]

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102899 - Optimisation and Optimal Control for Differential Equations

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**Prerequisites**  
none
3.174 Course: Optimization in Banach Spaces [T-MATH-105893]

**Responsible:** Prof. Dr. Roland Griesmaier  
PD Dr. Frank Hettlich  

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102924 - Optimization in Banach Spaces

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**Competence Certificate**  
oral examination of approximately 30 minutes

**Prerequisites**  
none

**Recommendation**  
Some basic knowledge of finite dimensional optimization theory and functional analysis is desirable.
### 3.175 Course: Optimization of Dynamic Systems [T-ETIT-100685]

**Responsible:** Prof. Dr.-Ing. Sören Hohmann

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-100531 - Optimization of Dynamic Systems

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**Events**

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<td>Optimization of Dynamic Systems</td>
<td>Hohmann</td>
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**Exams**

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<td>Optimization of Dynamic Systems</td>
<td>Hohmann</td>
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</table>

**Prerequisites**

none

**Competence Certificate**

The assessment consists of a written exam (120 min) taking place in the recess period.

**Legend:** 🖥 Online, ☑️ Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
3.176 Course: Oral Exam - Supplementary Studies on Culture and Society [T-ZAK-112659]

Responsibility: Dr. Christine Mielke
Christine Myglas

Organisation:
Part of: M-ZAK-106235 - Supplementary Studies on Culture and Society

Type: Oral examination
Credits: 4
Grading scale: Grade to a third
Version: 1

Competence Certificate
An oral examination according to § 7 section 6 of approx. 45 minutes on the contents of two courses from In-depth Module.

Prerequisites
Prerequisite for the 'Oral Examination' is the successful completion of Modules 1 and 3 and the required elective sections in Module 2.
3.177 Course: Oral Exam - Supplementary Studies on Sustainable Development [T-ZAK-112351]

Organisation:
Part of: M-ZAK-106099 - Supplementary Studies on Sustainable Development

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Competence Certificate
An oral examination according to § 7 section 6 of approx. 45 minutes on the contents of two courses from Elective Module.

Prerequisites
A requirement for the Supplementary Course: Oral examination is the successful completion of the modules Basics Module and Specialisation Module and the required electives of Elective Module.
3.178 Course: Parallel Computing [T-MATH-102271]

**Responsible:** PD Dr. Mathias Krause
Prof. Dr. Christian Wieners

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-101338 - Parallel Computing

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Techno-Mathematics Master 2016 (Master of Science (M.Sc.))
Module Handbook as of 05/03/2024
### 3.179 Course: Particle Physics I [T-PHYS-102369]

**Responsible:**
- Prof. Dr. Torben Ferber
- Prof. Dr. Ulrich Husemann
- Prof. Dr. Markus Klute
- Prof. Dr. Günter Quast
- PD Dr. Klaus Rabbertz

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102114 - Particle Physics I

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**Events**

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<td>Particle Physics I</td>
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<td>Lecture / 🗣</td>
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<td>WT 23/24</td>
<td>4022032</td>
<td>Exercises to Particle Physics I</td>
<td>2</td>
<td>/ 🗣</td>
<td>Ferber, Chwalek</td>
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</table>

*Legend: 📱 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled*

**Prerequisites**

none
### 3.180 Course: Pattern Recognition [T-INFO-101362]

**Responsible:** Prof. Dr.-Ing. Jürgen Beyerer  
Tim Zander

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100825 - Pattern Recognition

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**Events**

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<th>Type</th>
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<td>Lecture / Practice</td>
<td>4 SWS</td>
<td>Lecture / Practice</td>
<td>Beyerer</td>
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<td>Lecture / Practice</td>
<td>4 SWS</td>
<td>Lecture / Practice</td>
<td>Beyerer</td>
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</table>

Below you will find excerpts from events related to this course:

**Pattern Recognition**  
24675, SS 2024, 4 SWS, Language: German, Open in study portal

**Organizational issues**

Vorlesung: montags 15:45 bis 16:30 Uhr und mittwochs 14:00 bis 15:30 Uhr  
Übung: montags 16:30 bis 17:15 Uhr

**Literature**

Weiterführende Literatur

3.181 Course: Percolation [T-MATH-105869]

**Responsible:** Prof. Dr. Daniel Hug
Prof. Dr. Günter Last
PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102905 - Percolation

**Type**
Oral examination

**Credits**
5

**Grading scale**
Grade to a third

**Version**
2

**Prerequisites**
none
### 3.182 Course: Physical Foundations of Cryogenics [T-CIWVT-106103]

**Responsible:** Prof. Dr.-Ing. Steffen Grohmann  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103068 - Physical Foundations of Cryogenics

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#### Type
- Oral examination
- 6 Credits
- Grade to a third
- Each summer term
- Version 1

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<td>ST 2024 2250130</td>
<td>Physical Foundations of Cryogenics</td>
<td>2 SWS</td>
<td>Lecture / Grohmann</td>
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<tr>
<td>ST 2024 2250131</td>
<td>Physical Foundations of Cryogenics - Exercises</td>
<td>1 SWS</td>
<td>Practice / Grohmann</td>
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<td>Physical Foundations of Cryogenics</td>
<td>Grohmann</td>
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**Competence Certificate**  
Learning control is an oral examination lasting approx. 30 minutes.

**Prerequisites**  
None

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 👤 On-Site, ✗ Cancelled
3.183 Course: Poisson Processes [T-MATH-105922]

**Responsible:**
- Prof. Dr. Vicky Fasen-Hartmann
- Prof. Dr. Daniel Hug
- Prof. Dr. Günter Last
- Dr. Franz Nestmann
- PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics

**Part of:**
- M-MATH-102922 - Poisson Processes

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**Events**

| ST 2024 | 0152700 | Der Poisson-Prozess | 2 SWS | Lecture | Nestmann |

**Prerequisites**

none
3.184 Course: Potential Theory [T-MATH-105850]

**Responsible:**
- PD Dr. Tilo Arens
- Prof. Dr. Roland Griesmaier
- PD Dr. Frank Hettlich
- Prof. Dr. Wolfgang Reichel

**Organisation:**
- KIT Department of Mathematics

**Part of:**
- M-MATH-102879 - Potential Theory

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</table>
3.185 Course: Practice Module [T-ZAK-112660]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**
Part of: M-ZAK-106235 - Supplementary Studies on Culture and Society

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**Competence Certificate**

Internship (3 ECT)

Report within the framework of the practical training (Length approx. 18,000 characters (incl. spaces) (1 ECT)

**Prerequisites**

none

**Annotation**

Knowledge from the Basic Module and the Elective Module is helpful.

**Responsible:** Prof. Dr. Daniel Hug
Prof. Dr. Günter Last

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102947 - Probability Theory and Combinatorial Optimization

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**Prerequisites:**
none
### 3.187 Course: Process Modeling in Downstream Processing [T-CIWVT-106101]

**Responsible:** apl. Prof. Dr. Matthias Franzreb

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** M-CIWVT-103066 - Process Modeling in Downstream Processing

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<td>Each winter term</td>
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**Events**

| ST 2024 | 2214110 | Process Modeling in Downstream Processing | 2 SWS | Lecture / 🗣 | Franzreb |

**Exams**

| WT 23/24 | 7223015 | Process Modeling in Downstream Processing | Franzreb |

**Prerequisites**

None
### 3.188 Course: Processing of Nanostructured Particles [T-CIWVT-106107]

**Responsible:** Prof. Dr.-Ing. Hermann Nirschl  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103073 - Processing of Nanostructured Particles

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**Events**

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<td>Each winter term</td>
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**Exams**

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**Legend:** 🖥 Online, 📫 Blended (On-Site/Online), 🗣️ On-Site, ✗ Cancelled

**Prerequisites**
None
### Course: Random Graphs and Networks [T-MATH-112241]

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<th>Prof. Dr. Daniel Hug</th>
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<tr>
<td>Part of:</td>
<td>M-MATH-106052 - Random Graphs and Networks</td>
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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
none

**Recommendation**
The contents of the module 'Probability Theory' are strongly recommended.
### 3.190 Course: Real-Time Systems [T-INFO-101340]

**Responsible:** Prof. Dr.-Ing. Thomas Längle  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100803 - Real-Time Systems

<table>
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<td>4 SWS</td>
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<td>Längle, Ledermann</td>
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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗝 On-Site, ✗ Cancelled
3.191 Course: Regularity for Elliptic Operators [T-MATH-113472]

**Responsible:** apl. Prof. Dr. Peer Kunstmann

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106696 - Regularity for Elliptic Operators

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**Competence Certificate**
oral exam of ca. 30 minutes

**Prerequisites**
none
### 3.192 Course: Riemann Surfaces [T-MATH-113081]

**Responsible:** Prof. Dr. Frank Herrlich  
**Organisation:** KIT Department of Mathematics  
**Part of:** [M-MATH-106466 - Riemann Surfaces](#)  

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<td>WT 23/24</td>
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**Competence Certificate**  
Oral examination of ca. 30 minutes.

**Prerequisites**  
none
3.193 Course: Robotics I - Introduction to Robotics [T-INFO-108014]

**Responsible:** Prof. Dr.-Ing. Tamim Asfour

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100893 - Robotics I - Introduction to Robotics

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**Exams**

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Competence Certificate**

The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

**Prerequisites**

none.
**3.194 Course: Robotics II - Humanoid Robotics [T-INFO-105723]**

**Responsible:** Prof. Dr.-Ing. Tamim Asfour  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-102756 - Robotics II - Humanoid Robotics

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**Exams**

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**Competence Certificate**
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

**Recommendation**
Having visited the lectures on Robotics I - Introduction to Robotics and Mechano-Informatics and Robotics is recommended.

**Below you will find excerpts from events related to this course:**

**Robotics II: Humanoid Robotics**  
2400074, SS 2024, 2 SWS, Language: English, Open in study portal  
Lecture (V)  
On-Site

**Content**
The lecture presents current work in the field of humanoid robotics that deals with the implementation of complex sensorimotor and cognitive abilities. In the individual topics different methods and algorithms, their advantages and disadvantages, as well as the current state of research are discussed.

The topics addressed are: Applications and real world examples of humanoid robots; biomechanical models of the human body, biologically inspired and data-driven methods of grasping, imitation learning and programming by demonstration; semantic representations of sensorimotor experience as well as cognitive software architectures of humanoid robots.

**Learning Objectives:**
The students have an overview of current research topics in autonomous learning robot systems using the example of humanoid robotics. They are able to classify and evaluate current developments in the field of cognitive humanoid robotics. The students know the essential problems of humanoid robotics and are able to develop solutions on the basis of existing research.

**Organizational issues**
Die Erfolgskontrolle erfolgt in Form einer schriftlichen Prüfung im Umfang von i.d.R. 60 Minuten nach § 4 Abs. 2 Nr. 1 SPO.  
Arbeitsaufwand: 90 h  
Empfehlung: Der Besuch der Vorlesungen Robotik I – Einführung in die Robotik und Mechano-Informatik in der Robotik wird empfohlen  
Zielgruppe: Modul für Master Informatik, Master Maschinenbau, Mechatronik und Informationstechnik, Elektrotechnik und Informationstechnik

**Literature**
Weiterführende Literatur  
Wissenschaftliche Veröffentlichungen zum Thema, werden auf der VL-Website bereitgestellt.
Course: Robotics III - Sensors and Perception in Robotics [T-INFO-109931]

Responsible: Prof. Dr.-Ing. Tamim Asfour
Organisation: KIT Department of Informatics
Part of: M-INFO-104897 - Robotics III - Sensors and Perception in Robotics

Type: Written examination  Credits: 3  Grading scale: Grade to a third
Recurrence: Each summer term  Version: 2

Events
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Competence Certificate
The assessment is carried out as a written examination (§ 4 Abs. 2 No. 1 SPO) lasting 60 minutes.

Prerequisites
none.

Modeled Conditions
The following conditions have to be fulfilled:

1. The course T-INFO-101352 - Robotics III - Sensors in Robotics must not have been started.

Recommendation
Attending the lecture Robotics I – Introduction to Robotics is recommended.

Below you will find excerpts from events related to this course:

Content
The lecture supplements the lecture Robotics I with a broad overview of sensors used in robotics. The lecture focuses on visual perception, object recognition, semantic scene interpretation and (inter-)active perception. The lecture is divided into two parts:

In the first part a comprehensive overview of current sensor technologies is given. A basic distinction is made between sensors for the perception of the environment (exteroceptive) and sensors for the perception of the internal state (proprioceptive).

The second part of the lecture concentrates on the use of exteroceptive sensors in robotics. The topics covered include tactile exploration and visual data processing, including advanced topics such as feature extraction, object localization, semantic scene interpretation and (inter-)active perception.

Learning Objectives:
Students know the main sensor principles used in robotics and understand the data flow from physical measurement through digitization to the use of the recorded data for feature extraction, state estimation and environmental modeling.

Students are able to propose and justify suitable sensor concepts for common tasks in robotics.
Organizational issues
Die Erfolgskontrolle erfolgt in Form einer schriftlichen Prüfung im Umfang von i.d.R. 60 Minuten nach § 4 Abs. 2 Nr. 1 SPO.

Modul für Master Maschinenbau, Mechatronik und Informationstechnik, Elektrotechnik und Informationstechnik

Empfehlungen: Der Besuch der Vorlesung Robotik I – Einführung in die Robotik wird empfohlen

Zielgruppe: Die Vorlesung richtet sich an Studierende der Informatik, der Elektrotechnik und des Maschinenbaus sowie an alle Interessenten an der Robotik.

Arbeitsaufwand: 90 h

Literature
Eine Foliensammlung wird im Laufe der Vorlesung angeboten.

Begleitende Literatur wird zu den einzelnen Themen in der Vorlesung bekannt gegeben.
### 3.196 Course: Ruin Theory [T-MATH-108400]

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**Responsible:** Prof. Dr. Vicky Fasen-Hartmann  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-104055 - Ruin Theory  

**Prerequisites**
none
### 3.197 Course: Scattering Theory [T-MATH-105855]

**Responsible:**
- PD Dr. Tilo Arens
- Prof. Dr. Roland Griesmaier
- PD Dr. Frank Hettlich

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102884 - Scattering Theory

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3.198 Course: Scattering Theory for Time-dependent Waves [T-MATH-113416]

**Responsible:** Prof. Dr. Roland Griesmaier

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-106664 - Scattering Theory for Time-dependent Waves

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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
none
Course: Selected Methods in Fluids and Kinetic Equations [T-MATH-111853]

Organisation: KIT Department of Mathematics
Part of: M-MATH-105897 - Selected Methods in Fluids and Kinetic Equations

Type: Oral examination
Credits: 3
Grading scale: Grade to a third
Recurrence: Irregular
Expansion: 1 terms
Version: 1

Competence Certificate
oral examination of approx. 30 minutes

Prerequisites
none

Recommendation
The courses "Classical Methods for Partial Differential Equations" and "Functional Analysis" are recommended.
### 3.200 Course: Selected Topics in Harmonic Analysis [T-MATH-109065]

| **Responsible:** | Prof. Dr. Dirk Hundertmark |
| **Organisation:** | KIT Department of Mathematics |
| **Part of:** | M-MATH-104435 - Selected Topics in Harmonic Analysis |

| **Type**       | Oral examination |
| **Credits**    | 3 |
| **Grading scale** | Grade to a third |
| **Recurrence** | Irregular |
| **Version**    | 1 |

**Prerequisites**
none
### 3.201 Course: Self-Booking-HOC-SPZ-ZAK-1-Graded [T-MATH-111515]

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102994 - Key Competences

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**Self service assignment of supplementary studies**  
This course can be used for self service assignment of grade acquired from the following study providers:

- House of Competence  
- Sprachenzentrum  
- Zentrum für Angewandte Kulturwissenschaft und Studium Generale

**Annotation**  
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the “Sprachenzentrum” or the Center for Applied Cultural Studies and Studium Generale.
### 3.202 Course: Self-Booking-HOC-SPZ-ZAK-2-Graded [T-MATH-111517]

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102994 - Key Competences

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**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Zentrum für Angewandte Kulturwissenschaft und Studium Generale

**Annotation**
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the “Sprachenzentrum” or the Center for Applied Cultural Studies and Studium Generale.
3.203 Course: Self-Booking-HOC-SPZ-ZAK-5-Ungraded [T-MATH-111516]

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102994 - Key Competences

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**Self service assignment of supplementary studies**
This course can be used for self service assignment of grade acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Zentrum für Angewandte Kulturwissenschaft und Studium Generale

**Annotation**
Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachzentrum" or the Center for Applied Cultural Studies and Studium Generale.
### 3.204 Course: Self-Booking-HOC-SPZ-ZAK-6-Ungraded [T-MATH-111520]

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**Self service assignment of supplementary studies**

This course can be used for self service assignment of grade acquired from the following study providers:

- House of Competence
- Sprachenzentrum
- Zentrum für Angewandte Kulturwissenschaft und Studium Generale

**Annotation**

Placeholder for self-booking of a graded interdisciplinary qualification, which was provided at the House of Competence, the "Sprachenzentrum" or the Center for Applied Cultural Studies and Studium Generale.
### 3.205 Course: Semigroup Theory for the Navier-Stokes Equations [T-MATH-113415]

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<th><strong>Responsible:</strong></th>
<th>Dr. rer. nat. Patrick Tolksdorf</th>
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**Competence Certificate**
oral exam of ca. 30 min

**Prerequisites**
none
3.206 Course: Seminar Advanced Topics in Parallel Programming [T-INFO-103584]

**Responsible:** Prof. Dr. Achim Streit

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-101887 - Seminar Advanced Topics in Parallel Programming

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<td>Each summer term</td>
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3.207 Course: Seminar Mathematics [T-MATH-105686]

**Responsible:** PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102730 - Seminar

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**Exams**

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<td>Seminar Mathematics</td>
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</table>
### 3.208 Course: Signal Processing with Nonlinear Fourier Transforms and Koopman Operators [T-ETIT-113428]

**Responsible:** Prof. Dr.-Ing. Sander Wahls  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-106675 - Signal Processing with Nonlinear Fourier Transforms and Koopman Operators

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<th>2 SWS</th>
<th>Lecture / 🗣️</th>
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**Legend:** 🖥 Online, 🤴 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

**Competence Certificate**
The examination in this module consists of programming assessments and a graded written examination of 120 minutes.

The programming assignments are either pass or fail. They must be passed during the lecture period for admission to the written examination.

The module grade is the grade of the written exam.

**Prerequisites**
none
**3.209 Course: Sobolev Spaces [T-MATH-105896]**

**Responsible:** Prof. Dr. Roland Schnaubelt  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102926 - Sobolev Spaces

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**Recommendation**

Some basic knowledge of (elementary) linear functional analysis is strongly recommended.
3.210 Course: Software Engineering II [T-INFO-101370]

**Responsible:** Prof. Dr.-Ing. Anne Koziolek
Prof. Dr. Ralf Reussner

**Organisation:** KIT Department of Informatics

**Part of:** M-INFO-100833 - Software Engineering II

<table>
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<th>Recurrence</th>
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<td>Each winter term</td>
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**Events**

| WT 23/24 | 24076 | Software Engineering II | 4 SWS | Lecture / 🗣 | Reussner |

**Exams**

| WT 23/24 | 7500054 | Software Engineering II | Reussner |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled

Below you will find excerpts from events related to this course:

**Software Engineering II**

24076, WS 23/24, 4 SWS, Language: German, [Open in study portal](#)

**Literature**

3.211 Course: Space and Time Discretization of Nonlinear Wave Equations [T-MATH-112120]

**Responsible:** Prof. Dr. Marlis Hochbruck

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105966 - Space and Time Discretization of Nonlinear Wave Equations

<table>
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<td>Irregular</td>
<td>1 terms</td>
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**Events**

| WT 23/24 | 0100018 | Space and time discretization of nonlinear wave equations | 3 SWS | Lecture | Hochbruck, Dörich |

| WT 23/24 | 7700138 | Space and Time Discretization of Nonlinear Wave Equations | Hochbruck, Dörich |

**Exams**

**Prerequisites**

none
## 3.212 Course: Spatial Stochastics [T-MATH-105867]

**Responsible:** Prof. Dr. Daniel Hug  
  Prof. Dr. Günter Last  
  PD Dr. Steffen Winter  

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102903 - Spatial Stochastics

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### Events

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**Prerequisites**  
none
### 3.213 Course: Special Topics of Numerical Linear Algebra [T-MATH-105891]

**Responsible:** PD Dr. Volker Grimm  
Prof. Dr. Marlis Hochbruck  
PD Dr. Markus Neher  

**Organisation:** KIT Department of Mathematics  

**Part of:** M-MATH-102920 - Special Topics of Numerical Linear Algebra  

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**Prerequisites:**

none
3.214 Course: Specialisation Module - Self Assignment BeNe [T-ZAK-112346]

Responsible: Christine Myglas
Organisation: Part of: M-ZAK-106099 - Supplementary Studies on Sustainable Development

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Competence Certificate
The monitoring occurs in the form of several supplementary courses, which usually comprise a presentation of the (group) project, a written elaboration of the (group) project as well as an individual term paper, if necessary with appendices (examination performances of other kind according to statutes § 5 section 3 No. 3 or § 7 section 7).

The presentation is usually with the accompanying practice partners, as well as the written paper.

Prerequisites
Active participation in all three mandatory components.

Self service assignment of supplementary studies
This course can be used for self service assignment of grade acquired from the following study providers:

- Zentrum für Angewandte Kulturwissenschaft und Studium Generale
- ZAK Begleitstudium

Recommendation
Knowledge from 'Basic Module' and 'Elective Module' is helpful.
### 3.215 Course: Spectral Theory - Exam [T-MATH-103414]

**Responsible:** Prof. Dr. Dorothee Frey  
PD Dr. Gerd Herzog  
apl. Prof. Dr. Peer Kunstmann  
Prof. Dr. Roland Schnaubelt  
Dr. rer. nat. Patrick Tolksdorf

**Organisation:** KIT Department of Mathematics
**Part of:** M-MATH-101768 - Spectral Theory

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**Events**

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**Competence Certificate**

Oral examination of approx. 30 minutes.

**Prerequisites**

none

Below you will find excerpts from events related to this course:

**Spectral Theory**

0163700, SS 2024, 4 SWS, [Open in study portal](#)

**Literature**

- J.B. Conway: A Course in Functional Analysis.
- D. Werner: Funktionalanalysis.
### 3.216 Course: Spectral Theory of Differential Operators [T-MATH-105851]

**Responsible:** Prof. Dr. Michael Plum  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102880 - Spectral Theory of Differential Operators

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### 3.217 Course: Splitting Methods for Evolution Equations [T-MATH-110805]

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**Prerequisites**
none
**3.218 Course: Statistical Learning [T-MATH-111726]**

**Responsible:** Prof. Dr. Mathias Trabs  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105840 - Statistical Learning

**Type**  
Oral examination

**Credits**  
8

**Grading scale**  
Grade to a third

**Version**  
1

**Competence Certificate**  
The module will be completed with an oral exam (approx. 30 min).

**Prerequisites**  
none

**Recommendation**  
The module "Introduction to Stochastics" is recommended. The module "Probability theory" is preferable.
3.219 Course: Statistical Thermodynamics [T-CIWVT-106098]

**Responsible:** Prof. Dr. Sabine Enders

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** M-CIWVT-103059 - Statistical Thermodynamics

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**Legend:** 🖥 Online, 🗣️ Blended (On-Site/Online), 🗣️ On-Site, ☑️ Cancelled

**Competence Certificate**
Learning control is an oral examination lasting approx. 30 minutes.

**Prerequisites**
Thermodynamics III
Course: Steins Method with Applications in Statistics [T-MATH-111187]

**Responsible:** Dr. rer. nat. Bruno Ebner  
Prof. Dr. Daniel Hug

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105579 - Steins Method with Applications in Statistics

---

**Type**  
Oral examination

**Credits**  
4

**Grading scale**  
Grade to a third

**Recurrence**  
Irregular

**Version**  
1

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**Prerequisites**  
none
### 3.221 Course: Stochastic Control [T-MATH-105871]

**Responsible:** Prof. Dr. Nicole Bäuerle  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102908 - Stochastic Control

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**Prerequisites**

none
3.222 Course: Stochastic Differential Equations [T-MATH-105852]

**Responsible:** Prof. Dr. Dorothee Frey  
Prof. Dr. Roland Schnaubelt

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102881 - Stochastic Differential Equations

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### 3.223 Course: Stochastic Geometry [T-MATH-105840]

**Responsible:** Prof. Dr. Daniel Hug  
Prof. Dr. Günter Last  
PD Dr. Steffen Winter

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102865 - Stochastic Geometry

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#### Events

| ST 2024 | 0152600 | Stochastic Geometry | 4 SWS | Lecture | Winter |
| ST 2024 | 0152610 | Tutorial for 0152600 (Stochastic Geometry) | 2 SWS | Practice | Winter |

Below you will find excerpts from events related to this course:

**Stochastic Geometry**  
0152600, SS 2024, 4 SWS, Open in study portal

**Content**

For some idea what this course is about see  
https://www.math.kit.edu/stoch/seite/raeumstoch-lehre/en
3.224 Course: Stochastic Information Processing [T-INFO-101366]

**Responsible:** Prof. Dr.-Ing. Uwe Hanebeck  
**Organisation:** KIT Department of Informatics  
**Part of:** M-INFO-100829 - Stochastic Information Processing

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗺 On-Site, ✗ Cancelled

Below you will find excerpts from events related to this course:

**Stochastic Information Processing**

**24113, WS 23/24, 3 SWS, Language: German, Open in study portal**

**Content**

In order to handle complex dynamic systems (e.g., in robotics), an in-step estimation of the system's internal state (e.g., position and orientation of the actuator) is required. Such an estimation is ideally based on the system model (e.g., a discretized differential equation describing the system dynamics) and the measurement model (e.g., a nonlinear function that maps the state space to a measurement subspace). Both system and measurement model are uncertain (e.g., include additive or multiplicative noise).

For continuous state spaces, an exact calculation of the probability densities is only possible in a few special cases. In practice, general nonlinear systems are often traced back to these special cases by simplifying assumptions. One extreme is linearization with subsequent application of linear estimation theory. However, this often leads to unsatisfactory results and requires additional heuristic measures. At the other extreme are numerical approximation methods, which only evaluate the desired distribution densities at discrete points in the state space. Although the working principle of these procedures is usually quite simple, a practical implementation often turns out to be difficult and especially for higher-dimensional systems it is computationally complex.

As a middle ground, analytical nonlinear estimation methods would therefore often be desirable. In this lecture the main difficulties in the development of such estimation methods are presented and corresponding solution modules are presented. Based on these building blocks, some analytical estimation methods are discussed in detail as examples, which are very suitable for practical implementation and offer a good compromise between computing effort and performance. Useful applications of these estimation methods are also discussed. Both known methods and the results of current research are presented.

**Organizational issues**

Der Prüfungstermin ist per E-Mail (gambichler@kit.edu) zu vereinbaren.

**Literature**

Weiterführende Literatur  
Skript zur Vorlesung
3.225 Course: Stochastic Simulation [T-MATH-112242]

**Responsible:** TT-Prof. Dr. Sebastian Krumscheid  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-106053 - Stochastic Simulation

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**Competence Certificate**  
oral exam of ca. 30 min

**Prerequisites**  
none
### 3.226 Course: Structural Graph Theory [T-MATH-111004]

**Responsible:** Prof. Dr. Maria Aksenovich  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-105463 - Structural Graph Theory

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**Prerequisites**  
none
### 3.227 Course: Technical Optics [T-ETIT-100804]

**Responsible:** Prof. Dr. Cornelia Neumann  
**Organisation:** KIT Department of Electrical Engineering and Information Technology  
**Part of:** M-ETIT-100538 - Technical Optics

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| WT 23/24 | 2313720 | **Technical Optics** | 2 SWS  
Lecture / 🗣 |         |
| WT 23/24 | 2313722 | **Technical Optics (Tutorial to 2313720)** | 1 SWS  
Practice / 🗣 |         |

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Neumann |

**Prerequisites**

none
3.228 Course: Technomathematical Seminar [T-MATH-105884]

**Responsible:** Prof. Dr. Tobias Jahnke
PD Dr. Stefan Kühnlein

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-102863 - Technomathematical Seminar

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Technomathematical Seminar
Below you will find excerpts from events related to this course:

**Telematics**

Course: Telematics [T-INFO-101338]

| Responsible: | Prof. Dr. Martina Zitterbart |
| Organisation: | KIT Department of Informatics |
| Part of: | M-INFO-100801 - Telematics |

### Content

The lecture covers (i.a.) protocols, architectures, as well as methods and algorithms, for routing and establishing reliable end-to-end connections in the Internet. In addition to various methods for media access control in local area networks, the lecture also covers other communication systems, e.g. circuit-switched systems such as ISDN. Participants should also have understood the possibilities for managing and administering networks.

Familiar with the contents of the lecture *Einführung in Rechnernetze* or comparable lectures is assumed.

### Learning Objectives

After attending this lecture, the students will

- have a profound understanding of protocols, architectures, as well as procedures and algorithms used for routing and for establishing reliable end-to-end connections in the Internet
- have a profound understanding of different media access control procedures in local networks and other communication systems like circuit-switched ISDN
- have a profound understanding of the problems that arise in large scale dynamic communication systems and are familiar with mechanism to deal with these problems
- be familiar with current developments such as SDN and data center networking
- be familiar with different aspects and possibilities for network management and administration

Students have a profound understanding of the basic protocol mechanisms that are necessary to establish reliable end-to-end communication. Students have detailed knowledge about the congestion and flow control mechanisms used in TCP and can discuss fairness issue in the context of multiple parallel transport streams. Students can analytically determine the performance of transport protocols and know techniques for dealing with specific constraints in the context of TCP, e.g., high data rates and low latencies. Students are familiar with current topics such as the problem of middle boxes on the Internet, the usage of TCP in data centers or multipath TCP. Students are also familiar with practical aspects of modern transport protocols and know practical ways to overcome heterogeneity in the development of distributed applications.

Students know the functions of (Internet) routing and routers and can explain and apply common routing algorithms. Students are familiar with routing architectures and different alternatives for buffer placement as well as their advantages and disadvantages. Students understand the classification into interior and exterior gateway protocols and have in-depth knowledge of the functionality and features of common protocols such as RIP, OSPF, and BGP. Students are also familiar with current topics such as label switching, IPv6 and SDN.

Students know the function of media access control and are able to classify and analytically evaluate different media access control mechanisms. Students have an in-depth knowledge of Ethernet and various Ethernet variants and characteristics, which especially includes current developments such as real-time Ethernet and data center Ethernet. Students can explain and apply the Spanning Tree Protocol.

Students know the architecture of ISDN and can reproduce the peculiarities of setting up the ISDN subscriber line. Students are familiar with the technical features of DSL.
Literature
### 3.230 Course: Theoretical Nanooptics [T-PHYS-104587]

| Responsible          | Prof. Dr. Markus Garst  
|                      | Prof. Dr. Carsten Rockstuhl |
| Organisation         | KIT Department of Physics |
| Part of              | M-PHYS-102295 - Theoretical Nanooptics |

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✗ Cancelled
3.231 Course: Theoretical Optics [T-PHYS-104578]

**Responsible:** PD Dr. Boris Narozhnyy  
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics  
**Part of:** M-PHYS-102277 - Theoretical Optics

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**Prerequisites**
none
### 3.232 Course: Thermodynamics III [T-CIWVT-106033]

**Responsible:** Prof. Dr. Sabine Enders  
**Organisation:** KIT Department of Chemical and Process Engineering  
**Part of:** M-CIWVT-103058 - Thermodynamics III

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**Events**

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**Exams**

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Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, 🗿 Cancelled

**Competence Certificate**

Learning control is a written examination lasting 90 minutes.

**Prerequisites**

None
3.233 Course: Thermodynamics of Interfaces [T-CIWVT-106100]

**Responsible:** Prof. Dr. Sabine Enders

**Organisation:** KIT Department of Chemical and Process Engineering

**Part of:** M-CIWVT-103063 - Thermodynamics of Interfaces

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**Events**

| ST 2024 | 2250050 | Thermodynamics of Interfaces | 2 SWS | Lecture / 🔴 | Enders |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🔴 On-Site, 🗑 Cancelled

**Competence Certificate**

Erfolgskontrolle ist eine mündliche Prüfung im Umfang von 30 Minuten.
3.234 Course: Time Series Analysis [T-MATH-105874]

**Responsible:**
Dr. rer. nat. Bruno Ebner
Prof. Dr. Vicky Fasen-Hartmann
Prof. Dr. Tilmann Gneiting
PD Dr. Bernhard Klar
Prof. Dr. Mathias Trabs

**Organisation:**
KIT Department of Mathematics

**Part of:**
M-MATH-102911 - Time Series Analysis

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**Events**

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<td>Lecture</td>
<td>Gneiting</td>
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<td>Tutorial for 0161100 (Time Series Analysis)</td>
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Below you will find excerpts from events related to this course:

**Time Series Analysis 0161100, SS 2024, 2 SWS, Language: English,** [Open in study portal]

**Content**
A time series is a sequence of data sequentially observed in time. The course provides an introduction to the theory and practice of statistical time series analysis. Topics covered include stationary and non-stationary stochastic processes, autoregressive and moving average (ARMA) models, model selection and estimation, state-space models and the Kalman filter, forecasting and forecast evaluation, and an outline of spectral techniques.
Course: Topological Data Analysis [T-MATH-111031]

**Responsible:** Prof. Dr. Tobias Hartnick  
Prof. Dr. Roman Sauer

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105487 - Topological Data Analysis

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**Prerequisites**
none
3.236 Course: Topological Genomics [T-MATH-112281]

Responsible: Dr. Andreas Ott
Organisation: KIT Department of Mathematics
Part of: M-MATH-106064 - Topological Genomics

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Competence Certificate
oral exam of ca. 20 min

Prerequisites
none
3.237 Course: Translation Surfaces [T-MATH-112128]

**Responsible:** Prof. Dr. Frank Herrlich

**Organisation:** KIT Department of Mathematics

**Part of:** M-MATH-105973 - Translation Surfaces

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**Prerequisites**
none
3.238 Course: Traveling Waves [T-MATH-105897]

**Responsible:** Dr. Björn de Rijk  
Prof. Dr. Wolfgang Reichel

**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102927 - Traveling Waves

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**Competence Certificate**
The module examination takes place in form of an oral exam of about 30 minutes. Please see under "Modulnote" for more information about the bonus regulation.

**Prerequisites**
none

**Recommendation**
The following background is strongly recommended: Analysis 1-4.
Below you will find excerpts from events related to this course:

**Uncertainty Quantification**
0164400, SS 2024, 2 SWS, Language: English, Open in study portal

**Content**
"There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – there are things we do not know we don't know." (Donald Rumsfeld)

In this class, we learn to deal with the known unknowns, a field called Uncertainty Quantification (UQ). We particularly focus on the propagation of uncertainties (e.g. unknown data, unknown initial or boundary conditions) through models (mostly differential equations) and leave other important questions of UQ (especially inference) aside. Given uncertain input, how uncertain is the output? The uncertainties are modeled as random variables, and thus the solutions of the equations become random variables themselves.

Thus we summarize the necessary foundations of probability theory, with a focus on modeling correlated and uncorrelated random vectors. Further-more, we will see that every uncertain parameter becomes a dimension in the problem. We are thus quickly led to high-dimensional problems. Standard numerical methods suffer from the so-called curse of dimensionality, i.e. to reach a certain accuracy one needs excessively many model evaluations. Thus we study the fundamentals of approximation theory.

The first part of the course ("how to do it") gives an overview on techniques that are used. Among these are:

- Sensitivity analysis
- Monte-Carlo methods
- Spectral expansions
- Stochastic Galerkin method
- Collocation methods, sparse grids

The second part of the course ("why to do it like this") deals with the theoretical foundations of these methods. The so-called "curse of dimensionality" leads us to questions from approximation theory. We look back at the very standard numerical algorithms of interpolation and quadrature, and ask how they perform in many dimensions.

**Organizational issues**
The course will be offered in flipped classroom format. This means that the lectures will be made available as videos; students will also have lecture notes. We meet in presence for the tutorials, and there will also be office hours.

**Literature**
### 3.240 Course: Variational Methods [T-MATH-110302]

- **Responsible:** Prof. Dr. Wolfgang Reichel
- **Organisation:** KIT Department of Mathematics
- **Part of:** M-MATH-105093 - Variational Methods

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**T 3.241 Course: Wavelets [T-MATH-105838]**

**Responsible:** Prof. Dr. Andreas Rieder  
**Organisation:** KIT Department of Mathematics  
**Part of:** M-MATH-102895 - Wavelets

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**Competence Certificate**
Mündliche Prüfung im Umfang von ca. 30 Minuten.

**Prerequisites**
none